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May 17-21, 2023

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On behalf of the organizing committee, we are pleased to announce that the ***9th*** *International Conference on Environmental Science and Technology* ***(ICOEST-2023)*** *is held in* **Sarajevo, Bosnia and Herzegovina on May 17-21, 2023***. 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

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SARAJEVO BOSNIA & HERZEGOVINA

Prevention of Mucilage on marine ecosystem by wastewater refinery approach: Struvite recovery

Emrah Sık[1], Recep Partal[2], Irfan Basturk[3], Ozgur Dogan[4], Birgul Elgis Ertay[5]

Abstract

Wastewater treatment with a passive approach has focused on removing phosphorus (P) and nitrogen (N) for many years because of their potential to cause eutrophication in water bodies. However, high amounts of N and P are found in municipal and industrial wastewater. The enormous amount of nutrients present is one of the main factors in the formation of Marine Mucilage. At the same time their nutrient content, these wastewaters offer a high potential for struvite recovery. In this study, the effects of mucilage formation which is an environmental problem, relationship the nutrient load, was investigated. To investigate this effect, physical-chemical water quality parameters such as pH, nutrients (PO_4^{3-}-P, NH_4^+-N, TP, TN), magnesium, and molecular ratios of N:P:Mg (stoichiometry) were used. The highest NH_4-N and PO_4-P precipitation were around 83% and 97.0%, respectively, at pH 8.7, N:P:Mg molar ratio of 1.5:1:1. Consequently, eutrophication monitoring and the need for implementing biological C, N, P-removal treatment options (struvite recovery etc.) for all wastewater discharges reaching to the inland seas is essential.

Keywords: mucilage, municipal wastewater, nutrient, struvite,

1. INTRODUCTION

Mucilage seen in the seas is a polysaccharide organic matter community secreted to the aquatic environment by phytoplankton in response to various stressful conditions. Mucilage settles on the seabed and causes the death of other living organisms in the environment and disrupts the marine ecosystem in the regions where it is found.

In recent years, the mucilage problem has become ever more prevalent in the maritime environment. Rising ocean temperatures, overfeeding, and pollution from human activities intensify the impacts of this problem. While the appearance of mucilage reduces the habitats available to marine species, it also poses a substantial threat to economic activities such as tourism. As a result, addressing the mucilage issue is critical for environmental conservation and sustainable growth [1], [2].

The growing mucilage problem in the world's waters is caused by factors such as over-nutrition and pollution from human activities. Over nutrition causes a rise in nitrates, phosphates, and other nutrients in saltwater, resulting in algal blooms. Algal blooms diminish ocean oxygen levels while also causing mucilage production.

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Because mucilage is plentiful in organic matter in saltwater, it includes a wide range of nutrients. As a result, removing mucilage is a critical issue for the natural balance of our seas and human activities [3], [4]. Because of the many components contained in the effluent, it creates a significant environmental hazard. These wastewaters comprise organic and inorganic chemicals, heavy metals, and nutrients that are created by human activity. These elements, particularly plant nutrients like nitrates and phosphates, are the primary variables that contribute to wastewater's negative environmental consequences. However, the nutrients in wastewater have the potential to be a useful resource for plant growth and other industrial purposes.

As a result, research on nitrogen recovery from wastewater has grown in recent years. This technology has the potential to generate economic advantages while decreasing negative environmental consequences by extracting nutrients from wastewater. These nutrients can be employed in a variety of applications, including agricultural and industrial fertilizer, feed additives, bioenergy, and aquaculture [5], [6].

Considering the economic and ecological damages it causes, it is important to reduce the pollutant load to the receiving marine environment in order to prevent the recurrence of mucilage formation [7]. In this study, struvite recovery approach using wastewater treatment plants is presented as a method to prevent mucilage formation. This method ensures the management of the nutrient cycle in the seas and prevents the formation of mucilage through the recovery and reuse of water from wastewater treatment plants. The aim of this study is to investigate the effectiveness and applicability of the struvite recovery approach in preventing mucilage formation and to offer a more sustainable solution for marine ecosystems.

2. MATERIALS AND METHODS

2.1. Wastewater Characteristic

The wastewater samples investigated in this study were obtained from Tuzla municipal WWTP located in Istanbul/Turkey. In the WWTP, in addition to carbon removal, nitrogen and phosphorus removal is also carried out. In the sludge treatment units of WWTP, the sludge (slurry) is thicken (gravity and decanter) and sent to anaerobic stabilization, then dewatered by a centrifuge before the sludge is removed from the plant. On the other hand, the supernatants occurred in the secondary treatment sludge thickening (TS) unit, the dewatering (DS) unit and the common supernatant mixture tank (SM) are collected in a pool and sent to beginning of the primary treatment unit (Figure 1). The supernatants characterization is given in Table 1. In this study, struvite precipitation studies were carried out with anaerobic digester supernatant (dewatering (DS)).

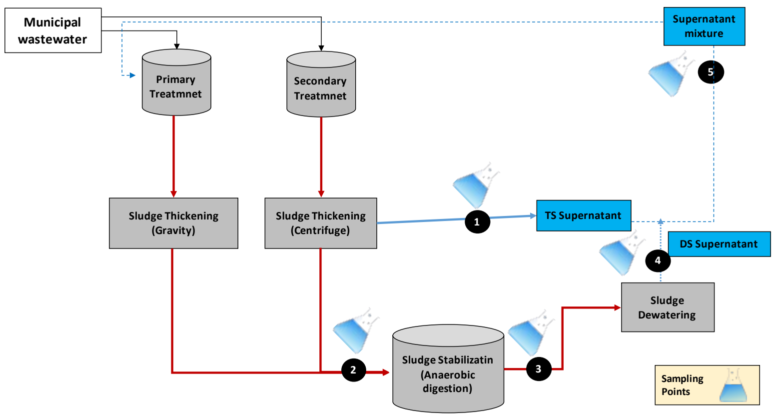

Figure 1. WWTP general flow chart and sampling points

Table 1. Wastewater samples characterization

Parameters	**Sludge thickening decanter (TS, sample point 1)**	**Dewatering decanter (DS, sample point 4)**	**Supernatant mixture tank (SM, sample point 5)**
pH	**7,3 ± 0,37**	**8,0 ± 0,24**	**7,6 ± 0,48**

Conductivity, mS/cm	**4,7 ± 1,8**	**8,2 ± 4**	**4,2 ± 0,7**
TKN, mg/L	**285,0 ± 150**	**680,2 ± 60**	**266 ± 105**
PO_4 - P, mg/L	**6,2 ± 3,0**	**9,0 ± 1,9**	**7,3 ± 2,3**
PO_4^{-3}, mg/L	**18,9 ± 13**	**27,5 ± 8**	**23,5 ± 8**
NH_4^+-N, mg/L	**40,3 ± 15**	**580,5 ± 25**	**162,1 ± 30**
COD, mg/L	**698 ± 375**	**495,2 ± 280**	**1070,5 ± 400**
AKM, gr/L	**4,5 ± 0,5**	**0,7 ± 0,1**	**2,3 ± 4**
Ca^{+2} (mg/L)	**110,1 ± 40,0**	**118,1 ± 13,0**	**97,9 ± 25,0**
Mg^{+2} (mg/L)	**68,5 ± 23,0**	**77,8 ± 6,6**	**51,7 ± 15,0**

2.2. Analytical methods

The pH and conductivity were measured by multimeter (HACH HQ40d). The chemical oxygen demand (COD) values were determined using Standard Methods [8]. Total Kjeldahl nitrogen (TKN), total phosphate (PO_4^{-3}), ortho-phosphate (PO_4-P) and ammonium-nitrogen (NH_4^+-N) concentrations were measured by an Ion Chromatography, metal concentrations were detected by using a Perkin Elmer ICP-MS.

2.3. Experimental procedure

Struvite precipitation experiments were conducted in a 1 L of a plexiglas conical reactor with a mechanical stirring, and pH and conductivity values were monitored simultaneously. The wastewater of 1 L (sampling points given in Figure 1) was transferred into a 1,5 L glass conical reactor. Then, the certain amount of caustic was dosed and the solutions were stirred at 300 rpm. The initial pH was adjusted to a certain value using NaOH and HCl. All experiments were carried out at room temperature. Magnesium chloride ($MgCl_2.6H_2O$) and ortho-phosphoric acid (H_3PO_4) were used as a supply of magnesium ions and phosphate.

The stirring speed was reduced to 100 rpm for 15 min and the glass reactor after 5 minute reaction time and it was covered with Parafilm™ and kept for 60 min at 25 °C. The liquid samples were filtered by 0.45 µm membrane filter for analyzes. The precipitates after the struvite experiments were dried at the room temperature for the analysis during 24 h, and then weighed for removal efficiency. The supernatant was collected and determine the percent recovery efficiency of nutrients (N, and P) as struvite were calculated according to Equation (1).

$$\%Recovery\ efficiency = \frac{(C_i - C_e)}{C_i} \times 100 \quad (1)$$

where C_i and C_e are the influent and effluent supernatant nutrient concentration, respectively.

3. RESULT AND DISCUSSION

All paragraphs must be justified, i.e. both left-justified and right-justified.

3.1. Effect of Wastewater pH on Precipitation

N, P, Mg molar ratio should be at a certain level in struvite precipitation, otherwise struvite formation will not be observed for the reason that under pH control. The pH has highly impact on both the crystallization and purity of struvite. In the studies in the literature, the pH range shows differences such as 8.5-9.5 [9], 7-10 [10] and 8.3 [11].

As a result of the literature review, the preliminary pH study for the struvite precipitation experiments carried out in this study was carried out with the thickening supernatant (TS), the dewatering supernatant (DS) and common supernatant mixture tank (SM) after anaerobic digestion wastewater samples. The efficiency of pH value was investigated at 8.0, 8.5, 9.0, 9.5,10.0 (natural pH of wastewater), and constant agitation speed of 150 rpm, the temperature of 20 °C. The addition of caustic, magnesium hydroxide, or lime can all be used to bring the pH level to the desired level [12, 13]. The pH level was adjusted using 3M and 1M NaOH in order to struvite precipitation. Figure 3 shows the pH shift that led to the development of struvite.

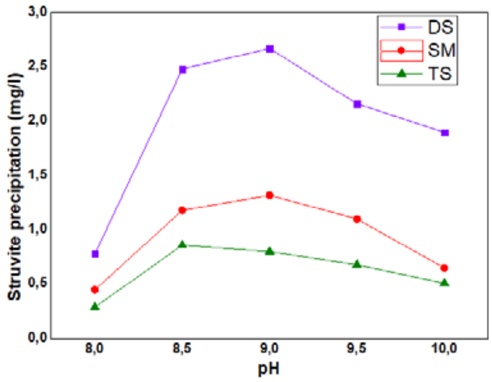

Figure 2. Effect of pH on struvite precipitation

The optimum pH value was found as 8.7 to ensure effective struvite recovery. This pH value will also reduce the risk of ammonia stripping. pH, a nutrient loss occurs due to the dissociation of ammonium ions from the solution, which has a negative effect on struvite precipitation [14, 15].

3.2. Pollution Load Assessment

Pollutants such as nitrogen and phosphorus entering into the aquatic environment are the food source for phytoplankton species. Due to the nutrients carried by the wastewater flowing into the Marmara Sea, a serious proliferation of algae and other phytoplankton has occurred in the sea. The entrance of land-based pollutants into the marine environment as a result of increasing urbanization and industrialization in especially coastal strips and eutrophication are the main reasons that trigger mucilage [16, 17]. The priority should be to reduce aquatic pollution and the production of all types of waste at source, including municipal wastewater. In order to address the problems posed by municipal wastewater, it is necessary to manage it properly. Today, recovery technologies allow most waste, including wastewaters, to be used as secondary raw material like struvite. Wastewater plants should be proper treatment and management because of have pollution load in large quantities. Struvite recovery is a green solution for preventing mucilage formation via decreasing the pollution loads at source on behalf of proactive approach. In this regard, Tuzla WWTP pollution loads were calculated and given in the Table 2. The nutrient pollutant load in Tuzla WWTP is shown in Figure 3 and Figure 4 for nitrogen and phosphorus, respectively.

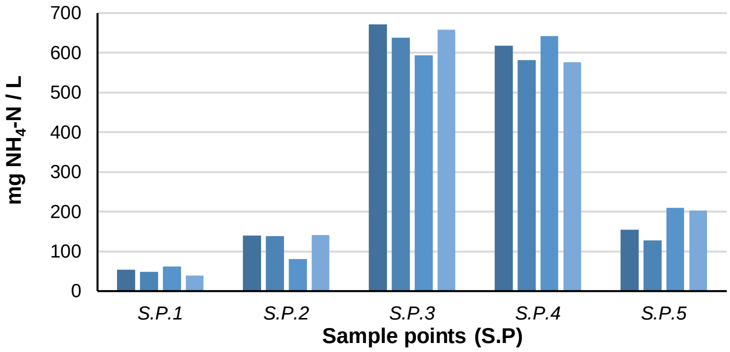

Figure 3. The ammonia nitrogen amount of sample points

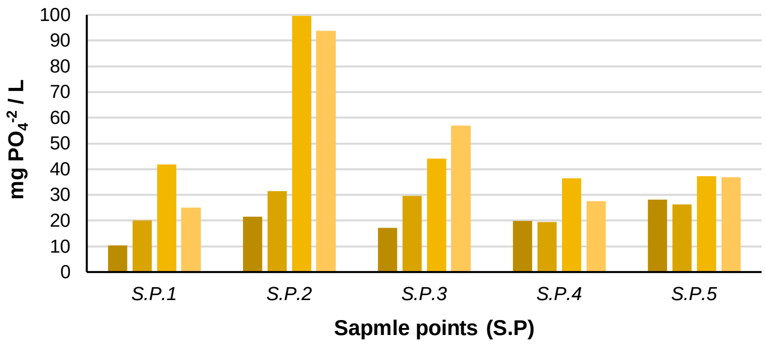

Figure 4. The phosphorus amount of sample points

Table 2. Tuzla WWTP pollution loads

Pollutant	**Amount (kg/day)**	**TS**	**DS**	**SM**	**Total** (kg/day)
	m^3/day	3460	2055	5515	
NH_4^+-N	mg/l	40	580	162	2223,8
PO_4-P	mg/l	6,2	9,0	7,3	80,21
Total	kg/day				2304,0
	After struvite precipitation				
NH_4^+-N	mg/l	25	171,5	48,9	708,6
PO_4-P	mg/l	2,8	2,3	3,0	30,97
Total	kg/day	96,2	357,1	286,3	739,6

The calculated total amount of pollutant discharge from supernatant point sources in 2022 was calculated as 2,22 tons of ammonia-nitrogen (NH_4^+-N), and 0.080 tons of ortho-phosphorus (PO_4-P) as seen in Table 2. As the point source pollution loads were mainly based on average of measured data in Tuzla WWTP. However, when struvite recovery from supernatants streams, the total amount of pollutant load were determined as 0.096 tone/day, 0.357 tone/day and 0.286 tone/day for TS, DS and MS, respectively.

3.3. Nutrients recovery by struvite precipitation

The primary purpose of this study was to struvite recovery, another efficiency that is of importance is the prevention of pollution in aquatic ecosystems caused by nutrient entry from the WWTP. Input and output concentrations of N, P, and Mg in the TS, DS, and MS supernatant samples under different N/P/Mg ratios and removal efficiency of nutrients were displayed in Figure 5. Theoretically, the molar ratio (stoichiometric ratio, N:P:Mg) required for struvite production demands magnesium additive. In this study, commercial magnesium chloride hydrate ($MgCl_2x12H_2O$) (Merck) was used as magnesium source. Three different stoichiometric ratios of 1.5:1:1, 1:1:1 and 1:0.5:0.5 were used in this study, respectively.

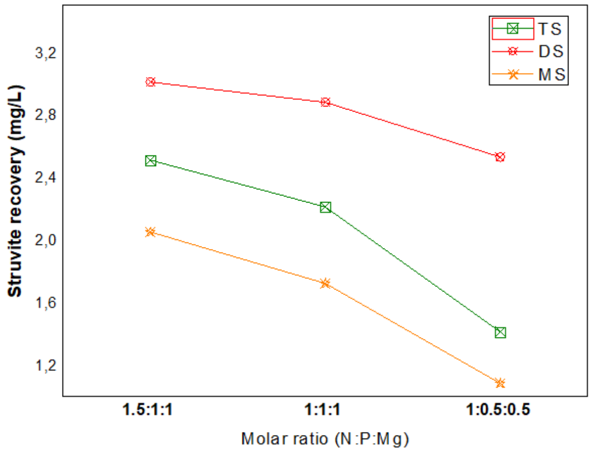

Figure 5. Struvite recovery quantity against different molar ratios for TS, DS and MS supernatants.

As seen in Figure 5 during this study, ammonia nitrogen removal efficiency varies between 37.5-70.4%, and ortho-phosphorus removal efficiency in the range of 54.8-74.4% were achieved within the three stoichiometric ratios. In fact, by recovering struvite, we have removed at least 37.5% of ammonia nitrogen and 54.8% of ortho-phosphorus that could cause eutrophication in the aquatic ecosystem, but by treating the central wastewater, we lighten the burden of the facility by returning the supernatants. These also reduce the maintenance and repair costs of the facility and reduce the time required for maintenance & repair. As the stoichiometry of the nutrients increases, the amount of struvite obtained also increases. In domestic wastewater treatment plants, nitrogen concentration is generally high, and phosphorus and magnesium are low, so it can be said that increasing the stoichiometric ratio depends on the nitrogen concentration at the wastewater point. The higher the Mg/P ratio, the higher the Mg and P removal efficiency. In this study, the economically optimum P: Mg ratio is 1:1. On the other hand, in the literature, the P/Mg ratio has been studied between 1.5:1 [18] and between 1 and 1.6 [19].

3.4. Characterization of Struvite

The N:P:Mg molar ratio of 1:1:1 for ***DS (Dewatering decanter, sample point 4)*** obtained precipitates was analyzed with XRD based on the Rietveld refinement at pH 8.7 (Figure 6) [20]. Quantitative analysis of crystalline minerals was established by means of the X-ray internal standard method. Method requires though that you can add a known amount of a suitable compound ("internal standard" e.g. zinc oxide) to your sample before the diffraction pattern. The internal standard must be 100% crystalline. As a result, absolute phase quantities are obtained. The difference to 100 weight-% determines the quantity of amorphous (and other unidentified crystalline) phases in the sample. There were strong peaks of struvite in precipitates formed at pH 8.7 and 1:1:1 ratio. Struvite crystals in crystal orthorhombic form ($Mg(NH_4)(PO_4)x6H_2O$) over 90%, brucite ($Mg(OH_2)$) form % 6 and potassium calcium phosphate hydrate form ($KCa(PO_4)xH_2O$) %1 were obtained in studies conducted at pH:8.7 with sample taken for DS. Under optimal conditions (pH 8.7 and 1:1:1), XRD analysis also demonstrated that struvite was the dominant composition of the precipitate.

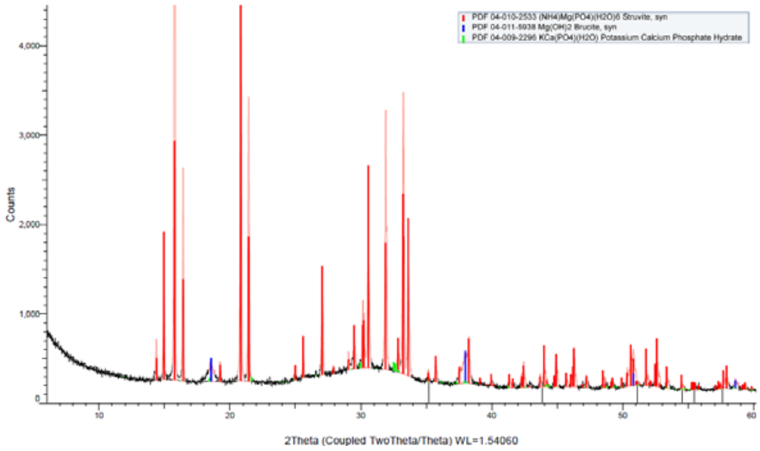

Figure 6. A sample line graph using colors which contrast well both on screen and on a black-and-white hardcopy

CONCLUSION

Consequently, using ISKI Tuzla WWTP digester supernatant (DS), thickening supernatant (TS), and the common supernatant mixture tank (SM) estimated that it was possible to recovery of the large amount of the struvite. Thus, nutrients such as N and P entering the aquatic environment will be significantly prevented at the source, which is a very feasible and promising method for the circular economy and wastewater refinery approach. In this study, at optimum struvite precipitation conditions for nitrogen and phosphorus removal by the recovery of nutrients from wastewaters; the pH value was determined as 8.7, and PO_4-P:Mg^{2+} ratio 1:1 was determined for supernatants. Under these conditions, nutrients recovery efficiency were obtained 70% ammonia nitrogen and 74% phosphorus respectively

In conclusion, the point source pollution was the main source of nitrogen, phosphorus, and COD had a significant effect on the mucilage formation of the removal of pollution. Such pollution sources are diverse and obligatory to supervise and control in order to preventing mucilage in the inland sea like Marmara Sea. For protect the marine ecosystem, renovating MWWTPs or improvement of MWWTPs to ensure high quality effluent to the inland sea will contribute to the protection of the marine ecosystem.

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REFERENCES

[1]. K. Ozhan, T. Katagan, D. Ediger, "A comprehensive review of mucilage (mucilage) as a marine pollutant", Journal of Environmental Management, vol. 183, pp. 831-840, 2016.

[2]. A. S. Ates, M. Sezgin, "Impacts of marine mucilage on the Turkish coasts of the Aegean and Mediterranean seas", Journal of the Marine Biological Association of the United Kingdom, pp. 1-11, 2021.

[3]. M. O. Karslioglu, T. Arslan, "Causes and impacts of marine mucilage: A review", Environmental Science and Pollution Research, vol. 27(28), pp. 34763-34778, 2020.

[4]. G. Turan, T. Katagan, K. Ozhan, "Investigating the environmental impact of mucilage in the Sea of Marmara", Marine Pollution Bulletin, vol. 149, 110514, 2019.

[5]. The European Environment Agency (EEA)., Marine Litter and microplastics, 2021.

[6]. A. M. El-Fadel, Z. Bou-Zeid, and R. Khorbotly, "Wastewater treatment and reuse in Lebanon: opportunities and challenges," Resources, Conservation and Recycling, vol. 50, no. 3, pp. 192-201, 2007.

[7]. J. C. García, J. A. García-Montiel, and R. J. Méndez-García, "Nutrient removal from wastewater by microalgae in a cascade of raceway ponds: Modeling and simulation," Bioresource Technology, vol. 150, pp. 387-394, 2013.

[8]. W.E.F. Apha, AWWA, Standard Methods for the Examination of Water and Wastewater, Amer. Pub. Heal. Assoc., Washingt. DC, 1995, p. 1998.

[9]. Bouropoulos, N. C. and Koutsoukos, P. G., 2000. "Spontaneous precipitation of struvite from aqueous solutions", Journal of Crystal Growth, 213: 381–388.

[10]. Stratful, I.; Scrimshaw, M.D.; Lester, J.N. 2004. "Removal of struvite to prevent problems associated with its accumulation in wastewater treatment works", Water Environmental Resource, 76, 437–443.

[11]. Buchynska, A., 2017. Phosphorus Recovery Through Struvite Precipitation: Testing of Parameters Which Enhance Phosphorus Recovery, Norwegian University of Life Sciences. Faculty of Environmental Science and Technology, Department of Environmental Sciences. Master's Thesis. Norway.

[12]. Fujimoto, N.; Mizuochi, T.; Togami, Y. Phosphorus fixation in the sludge treatment system of a biological phosphorus removal process. Water Sci. Tech. 1991, 23, 635–640.

[13]. Britton, A.; Koch, F.A.; Mavinic, D.S.; Adnan, A.; Oldham, W.K.; Udala, B. Pilot scale struvite recovery from anaerobic digester supernatant at an enhanced biological phosphorus removal wastewater treatment plant. J. Environ. Eng. Sci. 2005, 4(4), 265–277.

[14]. Doyle, J.D., Parsons, S.A., 2002. "Struvite formation, control and recovery", Water Research, 36(16): 3925-3940.

[15]. Adnan, A., Dastur, M., Mavinic, D.S., Koch, F.A., 2004. "Preliminary investigation into factors affecting controlled struvite crystallization at the bench scale", Journal of Environmental Engineering and Science, 3(3), 195–202.

[16]. Danovaro, R., Fonda Umani, S., Pusceddu, A. 2009. "Climate Change and the Potential Spreading of Marine Mucilage and Microbial Pathogens in the Mediterranean Sea", PLoS ONE 4(9): 7006.

[17]. Tufekci, V., Balkis, N., Polat Beken, C., Ediger, D. & Mantikci, M. 2010. "Phytoplankton composition and environmental conditions of a mucilage event in the Sea of Marmara", Turkish Journal of Biology, 34, 199-210.

[18]. Crutchik, D., Morales, N., Vázquez-Padín, J. R., Garrido J. M., 2017. "Enhancement of struvite pellets crystallization in a fullscale plant using an industrial grade magnesium product", Water Science and Technology, 75 (3): 609–618.

[19]. Rahaman, M. S., Ellis, N., & Mavinic, D. S. (2008). Effects of various process parameters on struvite precipitation kinetics and subsequent determination of rate constants. Water Science and Technology, 57(5), 647–654.

[20]. H. M. Rietveld, A Profile Refinement Method for Nuclear and Magnetic Structures," Journal of Applied Crystallography, 1969, 2, 65 – 71.

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Implications for marine pollution in a Chemical Tanker Collusions in the Strait of Canakkale (Dardanelles)

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

Abstract

The Turkish Straits Sea Area, which is a bridge and natural waterway connecting the Black Sea and Aegean Seas, has a very important geographical status. The Straits of Istanbul (Bosphorus) and Canakkale (Dardanelle) are the great natural way and also the Marmara Sea is the main component of the area. Contrary to Istanbul, there have been no major maritime accidents in the Canakkale. However, due to the changing and developing technology, ships have large tonnages. In addition, the investments of countries in energy transportation attract attention. Thus, chemical transportation has gained importance and there has been a change and development in the elements of maritime transportation. The Strait of Canakkale is characterized by settlements on both sides. Natural waterway areas with such characteristics need to be protected. In the study, a real-time simulation analysis was carried out in order to guide how much pollution will occur in a ship accident that may occur in a determined region in the Strait of Canakkale and to prevent the pollution that will occur there.

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

1. INTRODUCTION

As of May 2021, the Mucilage surrounding, especially the Sea of Marmara and the Turkish Straits Sea Area, is a gel-like and slippery mass composed of proteins, carbohydrates, and fatty acids secreted by microorganisms mostly gathered together and covering large areas. It is excreted from the body by single-celled organisms under stressful environmental conditions. While the Turkish Straits marine area is the waterway connecting the Caspian and Mediterranean Seas, the passage is essential for sea creatures. The mucilage effect in the filtration of ship systems arises from the seawater used by the ships during their passage through the straits in the cooling systems. Due to the protection of local and global maritime areas, a high level of attention is required, especially on the essential waterways located on the transit route of ships departing to many ports serving international transportation, such as the Turkish Straits.

The Republic of Turkey has a significant geopolitical and strategic position. Due to the straits, Turkey connects the continents of Asia and Europe. Also, the Turkish Straits are consisting of three major elements; Istanbul, Canakkale Straits, and the Marmara Sea. The Straits are a great example of the natural seaway of the world. Well-known Bosporus and Dardanelles names came from ancient times [1]. And these terms are not used anymore by Turkish authorities on the charts with geographic names. the Turkish strait sea area's all parts belong to the sovereign sea territory of Turkey and subject to the regime of internal waters by UNCLOS sentences. The Turkish Strait Sea Area is the most suitable and safe waterway in the region between the

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Mediterranean and the Black Sea due to its very important recent energy transportation. From 1936, The Turkish Straits, have been begun to govern by the Montreux Convention. The Montreux Convention has treaty obligations. Due to the obligation Republic of Turkey gave annual reports to the League of Nations Secretary-General firstly. Then since 1945, gave these reports to the United Nations Secretary-General. Reports had consisted of general information about straits and navigational safety etc. These reports, which also go to the High Contracting Parties, are entitled,'Rapport Annuel sur le Mouvement des Navires a Travers les Detroits Turcs' (Annual Report Concerning the Movement of Ships through the Turkish Straits). A very important detail in favor of using the expression the 'Turkish Straits' came from a United Nations document. This document belongs to the Third United Nations Conference on the Standardization of Geographical Names. This conference was held in Athens, in 1977, by 152 attended participants representing 59 countries, with observers from 11 non-governmental and international scientific organizations. The main aim of the Conference was to use national names to standardize the names of geographical locations. The resolutions of the conference empower Turkey in the use of the name 'Turkish Straits'. [3,4]. This conference's result document's title is proof of the international credence of the expression 'Turkish Straits'. [2,3,5] In recent years straits are the most important trade way of the world cause of the oil and oil products due to the energy transportation importance. Turkey is in the middle latitudes. So, it could easily feel like 4 season and their effects. Due to this reason, The Turkish Straits Sea Area has very special conditions in terms of the marine environment which includes atmospheric and oceanographic conditions, plant and animal diversity, and also the terrestrial environment. Many different marine species and fishes live and use straits for migration. The Turkish Straits have been exposed to dense marine traffic for centuries and a substantial increase has occurred in size and tonnage of the ships passing through the Straits with hazardous cargo varieties and amounts they carry by the neighboring Black Sea states and the Central Asian Turki Republics.Recently increase in the number of vessels that navigates on the Straits and being on the transportation way of hazardous goods pose serious environmental and safety hazards for the Turkish Straits Sea Area and its surrounding residential areas. High density of marine traffic effects on straits, makes the navigation rather difficult. The Straits have faced many casualties, collusions that caused severe environmental problems due to oil spilling [3,8]. The study shows the simulation and pollution of a possible accident while navigating the Strait of Canakkale (Dardanelle), a tanker that had an accident with the effect of Mucilage.

Fig. 1 The Turkish Strait Sea Area overview from paper chart number TR29.

2. THE CANAKKALE STRAIT OVERVIEW AND MARINE SCIENCE INFORMATIONS

The Canakkale Strait is one of major components of Turkish Strait Sea Area(TSSA). Canakkale strait is almost 20 NM longer than Istanbul strait. Canakkale's Morphological and geographical status is quite different of Istanbul strait [9]. The surveyed current direction of the Canakkale Strait is NE-SW. Between the Biga and Gelibolu peninsula areas are very narrow.[10,16] From Anafartalar to the north and the Biga ridge to the south of the Canakkale Strait has an average depth of -55 meters and reaches a depth of -90 meters. [16] Canakkale Strait constitutes 22% of the Turkish Straits Sea Area and the sea traffic separation lane is limited to 40 ° 26',00 N - 026 ° 45',25 E and 40 ° 01',52 N - 026 ° 11',18 E and has shown the Maritime Traffic Regulations for the Turkish Straits. The Canakkale Strait is defined between the longitude passing through Zincirbozan Lighthouse in the north and the line between Mehmetcik Cape Lighthouse - Kumkale Cape Lighthouse in the south [16].

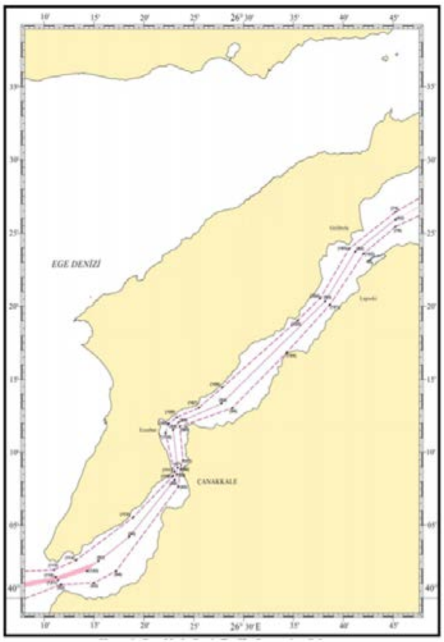

Fig. 2 The Canakkale Strait Traffic Seperation Scheme

Canakkale Strait has a different geography status than the Istanbul Strait. And also Canakkale straits length is 2 times longer than the Istanbul. But Canakkale's geomorphological structure, it has a rugged structure on the north and south line. The Canakkale Strait constitutes 22.56% of the Turkish Straits' sea area. Kilitbahir and Canakkale point is the narrowest part at the strait with1300 meters, the shore of Intepe and Domuz Dere is the widest part with 8135 meters. Not only The Istanbul Strait but also Canakkale Strait has two different currents. Both two strait's first current face is the surface current which comes from the Black Sea to the Aegean Sea through the Marmara Sea. and the second face or water collum the undercurrent coming from the first layer that the Mediterranean and passing through the Aegean Sea towards the Marmara Sea direction. Altough nearly 600 km3 of water lost annually(surveyed) by surface current coming from the Black Sea, it gains approximately 300 km3 of water per year thanks to the undercurrent coming from the Mediterranean Sea via the Turkish Straits. [13,16]. The surface current values between Marmara Sea to the Aegean Sea, are 0.5 and 5 knots. According to hydrographic surveyed that the this area's current speed reaches 2 knots per hour at Gelibolu. With geographic status and meteorological effects south side of Nara Cape and in front of Kilitbahir point, current value is 5 knots. Especially between Canakkale with Kepez area current value is also strong.

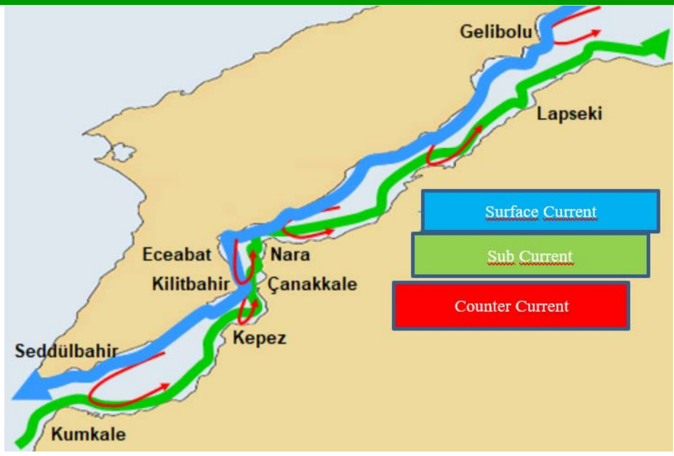

Fig. 3 Current Atlas of The Canakkale Strait [16].

3. THE REMARKABLE ACCIDENTS EXAMPLES OF THE TURKISH STRAITS

Turkey, also not produce energy, it is a passage that allows the passage of energy due to the geopolitical position. The Turkish Straits are the most important strategic gate point of the oil that passes from the Caspian to the Mediterranean, from the Middle East-Africa line to the Black Sea. The importance of our country in the energy market is gradually increasing, as the demand for energy in the world increases and is a bridge between Asia, Europe and the Middle East regions that import and export energy. Especially after Kazakhstan and Azerbaijan increased their oil production, export to countries such as France, Portugal, Spain, Italy and Greece through the Turkish Straits and Bulgaria's import 20% of its oil needs from Egypt besides Russia and Kazakhstan, It is an indicator of how important it is for our country.

Fig. 4 Independenta Tanker disaster in fornt of Haydarpasa Port.

On 15th November 1979, the collision happened between the M/T INDEPENDENTA(Romanian Flag) with the M/V Evriali (Greek Flag) in front of the Haydarpasa port at The Istanbul Strait. More than 30000 tonnes of crude oil were leaking from the M/T Independenta, the remaining 64000 tonnes were spilled into the Marmara Sea. Fire extinguishing and marine environmental cleaning operations lasted 56 days. During collusion, 42 crew members of two ships died in the ensuing explosion and fire on board the vessels and from burning oil on the Marmara Sea. Coastline Houses were reportedly damaged up to 6 km away.

Fig. 5 Nassia and Ship Broker vessels accident at the Strait of Istanbul.

On 13th March 1994, the collision happened between the M/T Nassia(Cyprus Flag) with M/V Shipbroker (Cyprus Flag) bulk carrier in front of the Ahirkapi anchorage area at The Istanbul Strait. Approximately 20000 tonnes of oil were spread around the Marmara Sea and most coastlines were covered with oil.

Fig. 6 M/V Vitaspirit collision at the Strait of Istanbul.

On 07 April 2018, at around 15:33, the Maltese flagged bulk carrier M/V Vitaspirit had a main engine failure during the south-north direction Istanbul Strait passage. The ship lost its steering power and left the planned route, and crashed into the 18th century Hekimbasi Salih Efendi mansion located at 41° 05.51' N & 029° 03.86'E.

4. MUCILAGE EFFECTS ON THE TURKISH STRAITS AND TANKER COLLISION SIMULATION

Mucilage has a different structure in marine habitats. It has known as foam or snow. Also known as aggregated mass, kind of flocs, cloud, or mucilaginous Especially in May 2021, many scientific studies were made about mucilage effects in the Sea of Marmara. These effects are ecological effects, tourism, fishing, and maritime transportation. However, there is a vast gap in the effect of mucilage on shipping. In this paper, a short review of the impact of mucilage on pumps, filters, and heat exchangers is examined and its effects on navigational safety. Furthermore, the ship's main engine and auxiliary systems malfunction due to lack of cooling is investigated. So, it would affect navigational safety both the Marmara Sea and the Turkish Straits during navigation.

Fig. 7 Mucilage Effects on the Marmara Sea during 2021.

Fig. 8 Mucilage Effects on the Strait of Canakkale during 2021

On May 2021, there was a huge marine polution that MUCILAGE (its still during on surface both Istanbul and Canakkale shorelines even reaches Aegean Coastline) covered all of the Canakkale shoreline surface.

Fig. 9 Mucilage effects on the vessels engine cooler system filters.

Images showes filters from ships cooler filters which voyaged from Istanbul and Canakkale Strait. Each filter clogged after the throat run, as in the photos, causing a malfunction in the cooling circuit. The mucilage layer, which keeps various shellfish and prevents it from getting water, harms not only the environment but also the working ships.

Fig. 10. The Strait of Canakkale from Kitab-I Bahri written by Piri Reis.

The maximum crude oil carrying load of a ship was 280 762 tons (ship / cargo) and the minimum cargo load was 0 (zero) tons for tankers passing through the Istanbul at once. The longest length of the tankers passing through the Istanbul Strait is 285.41 meters and the smallest length is 80 meters. When the width of the tankers is examined, the maximum length is 53 meters and the minimum length is 12.2 meters. The average crude oil transport load of these tankers passing through the Istanbul for the last 10 years is 97505 tons, their average length is 250.6 meters, their average width is 43.6 meters and their average speed is 12.8 knots. Between 2019 and 2020, it was trying to understand with simulation and surveyed in Canakkale Strait during oil spill various areas.

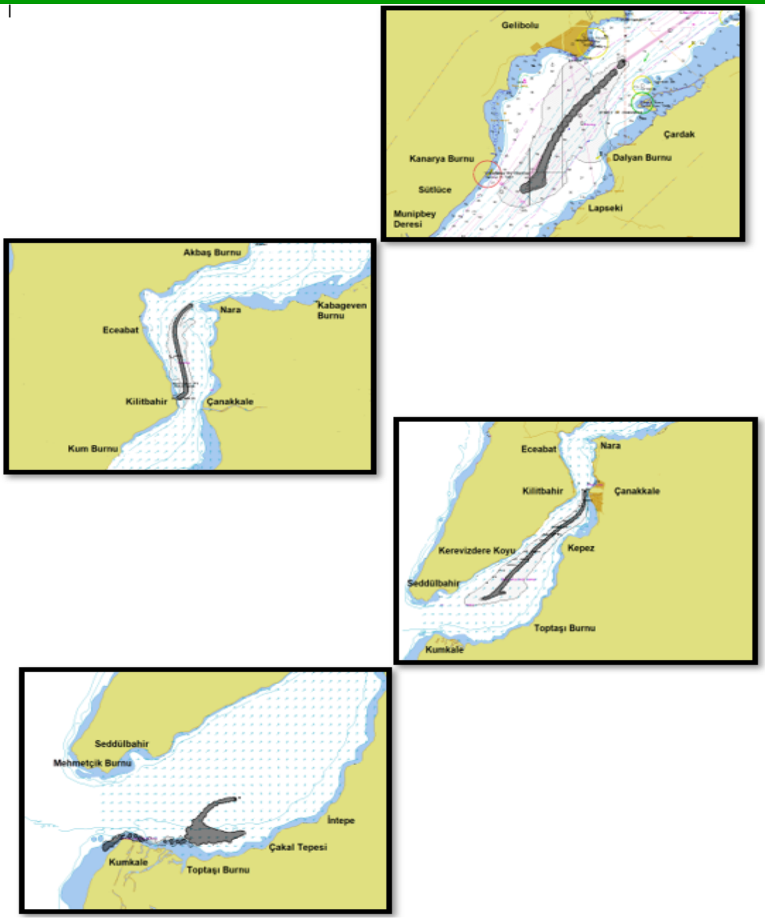

Fig. 11. Pollution according to the scenario of study.

CONCLUSION AND RESULTS

The mucilage effect on the ships showed its effect in the Turkish Straits and the Marmara Sea in May 2021, and the cleaning work started with the rapid reaction of the authorized bodies of the Republic of Turkey is significant. (T.R.Ministry of Environment, 2022)Mucilage cleaning works are significant for ships navigating the Turkish Straits and the Marmara Sea. The most crucial element of the ships sailing on a dynamic surface is their safety while navigating. The most crucial factor during the voyage is the safety of navigation. The Marmara Sea, the most significant component of the Turkish Straits Sea area, is an inland sea with a surface area of 11,350 square kilometers. As a result of oceanographic measurements, it has been understood that the low salty surface water from the Black Sea can be renewed every 5 to 6 months, and the salty bottom water from the Mediterranean can be renewed every 6 to 7 years. The mucilage structure felt in the Sea of Marmara in 2021 harms marine life; it has been determined that it forms at the bottom of the sea and on the sea's surface disrupts the life cycle. According to the latest findings, there are dense mucilage layers in the depth range of 5 to 30 m. Maritime transport is an essential part of global transport. Especially during the Pandemic, the importance of logistics, especially sea transportation, has increased a lot. With the increase in maritime transport, there has been an increase in the trade capacity and potential on the world's seas. IMO and maritime states have protected maritime seas with international and national regulations. However, although the regulations worked for control, they could not prevent the formation of the mucilage structure as in the Marmara Sea in May 2021. Mucilage plays a vital role in the daily working operations of the ship, especially in maritime transport. The water requirement from the sea is used in many areas in ship operations and is specially used as cooling water in machinery operations. Since the inlet places of the systems and circuits that draw water with the mucilage effect, especially the filter clogging will significantly and primarily affect the safety of navigation. Machine failures in areas with natural valley features such as the Sea of Marmara and especially the Turkish Straits can cause environmental pollution and loss of life and property.

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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, C.Gazioglu,A.G.Bora, ''Simulation of Marine Pollution from a Tanker Accident at the Canakkale Strait (Dardanelle)''6th ICOEST, 2020

[3]. 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

[4]. (1979) Third United Nations Conference on the Standardisation of Geographical Names

[5]. (2001) The Journal of International Affairs. Available http://sam.gov.tr/wp-content/uploads/2012/02/YukselInan.pdf

[6]. (2011) Political,Economic and Strategic and Dimension of the Turkish-Soviet Straits Question Emerged after World War II. International Journal of Business and Social Science, Vol.2, No.15,173-174

[7]. (1948) Bilsel, C. Turk Bogazlari, Istanbul

[8]. (2008) Birpinar,M.E.,Talu,G.F.,Gonencgil,B.,Environmental effects of maritime traffic on the Istanbul Strait

[9]. (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

[10]. (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

[11]. (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.

[12]. 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

[13]. 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.

[14]. 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).

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

[16]. 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

[17]. https://webdosya.csb.gov.tr/db/cygm/icerikler/dcep_-canakkale-20210617131448.pdf

[18]. https://www.harboroffshorebarriers.com/psb-5500/

BIOGRAPHY

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Capital Structure and Use of Raspberry-Growing Enterprises in Bosnia and Herzegovina: Zeljezno Polje Example

Eldina Muminovic[1], Cennet Oguz[2]

Abstract

The study's primary purpose is to determine the capital structure of raspberry production enterprises in Zeljezno Polje. It is important for agricultural enterprises to offer financing and credit to individual producers with appropriate terms. The data in the study refer to the 2021 production year and were obtained through a survey method from 91 enterprises, which were determined with a margin of error of 5% at the 95% confidence limit according to the stratified random sampling method. The enterprises examined in the field were classified according to their capital structure and functions, and the average active capital of the enterprises was calculated as $19,179.93. The ratio of active capital consists of 74.95% of land capital, 18.08% revolving working capital, and 6.97% fixed working capital. It has been determined that raspberry enterprises rely on their own capital instead of loans. There have been no similar studies conducted in the research area, and this article will make an important contribution to the literature.

Keywords: Capital, Raspberry Enterprises, Zeljezno Polje

.1 INTRODUCTION

In 2009, the world raspberry production area was approximately 97 thousand hectares. By 2021, the world raspberry production area had increased to approximately 111 thousand hectares. Raspberry production area increased from 92,895 hectares in 2013 to 127,578 hectares in 2019, which is an increase of 37% compared to 2013. World raspberry production has increased by approximately 60% since 2009, with 899,197 tons as the highest production in 2020 and 522,004 tons as the lowest production in 2010 (Table 1).

Table 2.Raspberry production area, production and yield status in the World by years

Years	Production area (ha)	Production quantitiy (tons)	Yield (ton/ha)
2009	96,931	533,580	5.71
2010	106,362	522,004	4.91
2011	107,091	599,451	5.60
2012	102,507	569,352	5.55
2013	92,895	588,278	6.33
2014	93,317	628,672	6.74
2015	101,203	674,934	6.67
2016	114,840	823,429	7.17

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2017	119,088	798,224	6.70
2018	126,114	850,422	6.74
2019	127,578	822,493	6.45
2020	110,173	899,197	8.16
2021	110,567	886,539	8.02

Resource: Food and Agricultural Organization, 2023

Although it varies according to the regions, Europe is the largest raspberry producer in the world. About 70% of raspberry production is produced in Europe (Table 2).

Table 3. Average raspberry production share by regions (2009-2021)

Area	Average raspberry production share (%)
Europe	69.59
America	28.22
Asia	2.03
Oceania	0.11
Africa	0.05

Resource: Food and Agricultural Organization, 2023

In table 2 in the period 2009-2021 69.59% of the total raspberry production was produced in Europe, 28.22% in America and 2.03% in Asia. According to FAO data the world's largest raspberry producers in 2021 were Russian Federation with 197,700 tons, Mexico is in the second place with 165,677 tons, Serbia is the third with 110,589 tons and Bosnia and Herzegovina is in the ninth place with 16,803 tons. Although the largest raspberry producer is Russia (Sredojevic et al. 2013, Kljajic 2017), all raspberry production in this country is generally consumed in the domestic market (Paszko et al. 2016), so it has no real impact on the global raspberry market. The 13 countries given in the table 3 constitute 91% of the world's raspberry production area. While 22.30% of the total raspberry production in the world belongs to Russia, 18.69% to Mexico and 12.47% to Serbia, 1.90% of the world's raspberry production is made by Bosnia and Herzegovina (Table 3). 95% of the world's raspberry production is carried out by these 13 countries.

Table 4. Important raspberry producing countries in the world (2021)

Countries	Production area (ha)	Production (ton)
Russia	23,809	197,700
Mexico	8,520	165,677
Serbia	20,807	110,589
Poland	19,800	103,900
America	6,758	81,150
Spain	2,420	48,830
Ukraine	5,400	36,290

Portugal	1,450	27,950
Bosnia and Herzegovina	2,686	16,833
Chile	3,824	15,934
England	1,456	15,694
Azerbaijan	2,636	11,866
Germany	1,020	7,020
Total	100,586	839,433
World	110,567	886,539
Ratio %	%91	%95

Resource: Food and Agricultural Organization, 2023

Bosnia and Herzegovina is an important country for developing various forms of agricultural production due to its favorable agricultural conditions, such as climate and soil. Although orchards cover only 8% of the arable land, the fruit production has shown a significant improvement in the last decade. According to the fruit and vegetable export guide, the export of fruits and vegetables from Bosnia and Herzegovina to the European Union is progressing steadily, with raspberry exports being the leading product of the increase in exports. Raspberry export in Bosnia and Herzegovina has an excellent margin and price in the global market, and its contribution to the national income is significant. Bosnia and Herzegovina ranks ninth in raspberry production in the world. Although the country provides positive economic results in terms of climate and soil conditions, new raspberry plantations are still based on small surface areas of 1-2 decares. It is important to note that there is a lower limit of economic cost-effectiveness in the production of raspberries. Raspberry production is also an essential raw material in the business industry. However, currently, raspberries are only exported fresh or frozen from Bosnia and Herzegovina. Processing and exporting raspberries will bring more added value to the country. Therefore, raspberry producers need to determine their current capital to plan for new investments and take future steps towards processing and exporting raspberries.

According to the FAO, the average annual raspberry production in Bosnia and Herzegovina for the period of 2009-2021 was 14,915 tons. During this period, the production was 7,016 tons in 2012, 27,466 tons in 2018, and 16,833 tons in 2020, with a decrease in production (Table 6).

Table 5. Raspberry production areas, production and yield in Bosnia and Herzegovina by years

Years	Production area (ha)	Production quantitiy (tons)	Yield (ton/ha)
2009	1,031	8,487	8.23
2010	1,114	7,937	7.12
2011	1,220	9,459	7.75
2012	1,240	7,016	5.66
2013	1,261	9,075	7.20
2014	1,415	10,613	7.50
2015	1,682	13,631	8.10
2016	2,647	22,160	8.37
2017	3,296	22,671	6.88
2018	3,500	27,466	7.85

2019	2,936	19,749	6.73
2020	2,825	18,794	6.65
2021	2,686	16,833	6.27

Resource: Food and Agricultural Organization, 2023

In 2021, raspberry was cultivated on 2,686 hectares of land, producing 16,833 tons, which is a 10% decrease compared to the previous year. The yield of fresh raspberry harvested per hectare was 6.27 tons, which is 5.71% lower than the previous year. The reduction of planted areas by 4.92% low yield, and the impact of the COVID-19 pandemic contributed to the decrease in production. Additionally, adverse weather conditions such as late frosts and winds in the spring followed by a long rainy period, resulted in weaker fruit set and increased disease in almost all fruit plantations. Furthermore, hail in certain regions of Bosnia and Herzegovina also affected the yield, resulting in a decrease in first-class fruits.

2. MATERIAL AND METHODS

The main material of the study was the data obtained from the survey conducted with raspberry enterprises in Zeljezno Polje. The data covers the production year 2021. The population of the research, the number of raspberry producing associations and cooperatives operating in Zeljezno Polje and the number of 1800 raspberry producing enterprises constituted the main frame of the research. The sample size of the study was calculated as 91 with a 5% margin of error at the 95% confidence interval, using the formula bellow, according to the non-clustered simple random sampling method based on the population ratios (Oguz and Karakayaci, 2017).

$$n=\frac{Np(1-p)}{(N-1)\sigma_{Px}^2+P(1-P)}=\frac{1800(1-0,50)}{(1800-1)0,0510^2+0,50(1-0,50)}=91$$

n=sample volume

N=population number of enterprises

σ_{Px}^2=variance of ratio

P=0.5

Raspberry enterprises were examined according to the raspberry land asset and it was found appropriate to form three groups. The boundaries of these groups are ≤1,0 decares; 1,1-2,0 decares and 2,1+ decares of raspberry land assets. The first group has 49 enterprises, the second group has 35 enterprises and the third group has 7 enterprises.

In the raspberry enterprises of Zeljezno Polje the distribution of capital is done by its functions (Acil and Demirci, 1974; Inan, 1994). According to this division, the capital is categorized as active and passive capital.

3. RESULTS AND DISCUSSION

The sustainability and development of raspberry enterprises depend on competitiveness. Determining the competitiveness performance of enterprises is possible by correctly presenting their capital structures. For this reason, the capital structures of raspberry enterprises were calculated by classifying them according to their functions.

3.1. Capital Structure in the Examined Enterprises

Active Capital

Active capital consists of farm capital and enterprise capital. Farm capital comprises land, land improvement, buildings, plants, hunting, and fish capital. However, as there is no hunting and fish capital in the examined enterprises, we will not discuss this capital group. Enterprise capital is important for activating the land capital within the active capital (Erkus, 1979). It is divided into two groups: fixed enterprise capital and revolving enterprise capital. Fixed enterprise capital consists of livestock capital and tool machine capital, while revolving enterprise capital consists of material and ammunition capital and money capital (Oguz and Bayramoglu, 2014).

The total active capital of the enterprises is summarized in the table below.

Table 6. Distribution and ratio of active capital in enterprises surveyed ($, %)

Capital groups		**Enterprise groups**							
		≤1,0		1,1-2,0		2,1+		Average	
		$	%	$	%	$	%	$	%
Farms capital	Land	2,551.55	18,78	3,780.14	28.38	7,778.06	41.42	3,926.12	27.31
	LIC	260.24	1,92	227.61	1.71	192.40	1.02	242.47	1.69
	Building	10,186.92	74,98	8,184.15	61.45	8,715.15	43.53	9,261.86	64.43
	Plant	588.33	4,33	1,126.59	8.46	2,632.77	14.02	944.70	6.57
	Total	13,587.04	100.00	13,318.49	100.00	18,778.38	100.00	14,375.15	100.00
			73.71		74.18		77.81		74.95
Fixed enterprises capital	Livestock	121.64	10.15	0.00	0.00	262.00	11.94	85.66	6.41
	TM	1,076.64	89.85	1,358.87	100.00	1,932.22	88.06	1,251.31	93.59
	Total	1,198.28	100.00	1,358.87	100.00	2,194.22	100.00	1,336.97	100.00
			6.50		7.57		9.09		6.97
Revolving enterprises capital	MSC	3,283.24	90.01	2,857.82	87.19	2,570.65	81.35	3,064.80	88.38
	MC	364.46	9.99	419.69	12.81	589.49	18.65	403.01	11.62
	Total	3,647.70	100.00	3,277.51	100.00	3,160.14	100.00		100.00
			19.79		18.25		13.09		18.08
Total farm capital		4,845.98	26.29	4,636.38	25.82	5,354.36	22.19	4,804.78	25.05
Total active capital		18,433.02	100.00	17,954.87	100.00	24,132.74	100.00	19,179.93	100.00

LIC: Land improve capital, TM: Tools machines, MSC: Materials and supplies capital, MC: Money capital, Resources: Calculated by the author according to reserach results

Active capital of $19,179.93 per enterprise has been determined. 75.95% of this is farm capital and 25.05% is working capital. In the first group, active capital is $18,433.02, in the second group $17,954.87, and in the third group $24,132.74. Active capital is equal to its equity capital.

The distribution of the capital elements that constitute active capital is important for effective business management. Therefore, it is essential to examine the active capital that comprises the enterprise capital according to its components. In a well-managed enterprise, the distribution of active capital is expected to be 25% for farm capital, 25% for building capital, 25% for livestock capital, 10% for tools and machine capital, 10% for material and supply capital, and 5% for money capital (Erkus, 1995).

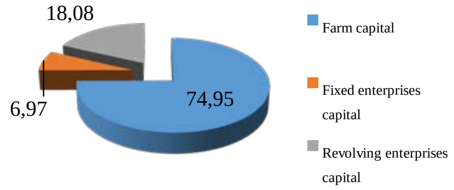

Figure 1. Proportional distribution of active capital in the examined enterprises (%)

In the examined enterprises, farm capital constitutes 74.95% of the active capital, while revolving enterprise capital and fixed enterprise capital account for 18.08% and 6.97%, respectively. Building capital has the highest rate among active capital components (48.29%), followed by farm capital (20.47%), material and supply capital (15.98%), tool and machine capital (6.52%), plant capital (4.93%), money capital (2,10%), land improvement capital (1,26%), and livestock capital (0.45%).

On average, the land capital of the enterprises was determined to be $3,926.12. The land is 100% privately owned.

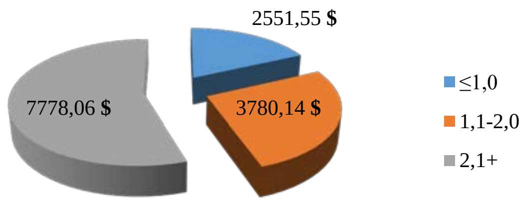

Figure 2. Land capital distribution in the examined enterprises ($)

Land capital varies according to the enterprises groups. Land capital for the first group is $2,551.55, for the second group $3,780.14 and for the third group $7,778.06.

Another capital element is land improvement capital. It constitutes the water well improvement capital in the examined enterprises. The cost criterium was taken as a basis of the calculation of the land improvement capital. The value of the existing land improvement capital was calculated by subtracting the depreciation cost from the value of the new one.

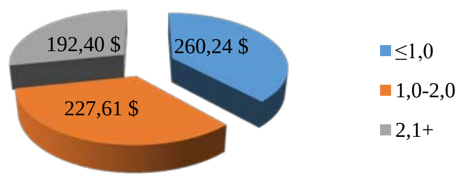

Figure 3. Distribution of land improvement capital in surveyed enterprises ($)

The average land improvement capital in the surveyed enterprises is $242.47. As shown in Figure 3, the land improvement capital for the first group is $260.24, for the second group $227.61, and for the third group $192.40.

Next capital element that contributes to the farm capital is the building capital. Building capital in enterprises consists of a farmer's house, a barn, and a warehouse. The average building capital per enterprise was determined to be $9,261.86.

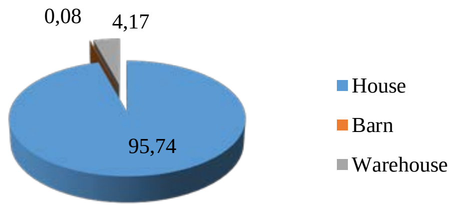

Figure 4. Building capital in surveyed enterprises (%)

The ratios of the elements that make up the building capital are given in Figure 4. Of the $9,261.86 building capital per business, 95.74% consists of houses, 4.17% consists of warehouses, and 0.08% consists of barn assets.

Another element that constitutes the farm capital is plant capital. Plant capital, which is included in farm capital, consists of the value of fruiting and non-fruiting trees as well as the value of field fixtures and equipment, which includes expenditures made for the next production period (Erkus, 1979). Fruiting and fruitless trees found in front of houses and on the sides of fields in the surveyed enterprises were not evaluated due to their low quantity. The average plant capital per enterprise is calculated as $944.70 and consists entirely of raspberry fruit trees.

Farm capital per enterprise is $14,375.15. The biggest share of this capital is the building capital at 64.43%.

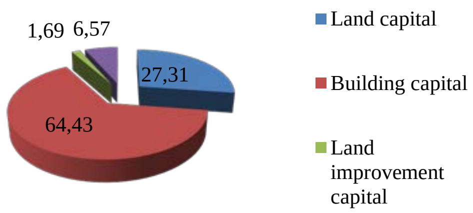

Figure 5. Proportional distribution of farm capital in surveyed enterprises (%)

The proportional distribution of farm capital in the examined enterprises is given in Figure 5. 64.43% of the total farm capital is building capital, 27.31% is land capital, 6.57% plant capital, and 1.69% land improve capital.

Livestock capital consists of all livestock in agricultural enterprises. The most important feature of this capital group is that it has the ability to reproduce itself. For this reason, this capital group is called living inventory. Animal capital is divided into two groups, as work and income animals. Livestock capital in examined enterprises consists of the sum of the values of income animals, since work animals are not encountered. There are cattle and bees as income animals in the enterprises. There are cows among the cattle. The proportional distribution of livestock capital in the examined enterprises is given in Figure 6.

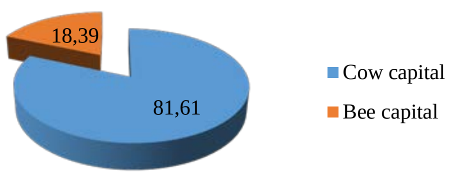

Figure 6. Proportional distribution of livestock capital in surveyed enterprises (%)

There are a total of 4 cows in the examined enterprises. There are also 15 beehives. For calculating livestock capital it was used market price criterion. A livestock capital of $85,66 per enterprise has been determined. For the first group of enterprises $121,64, for the second group $0,00, and for the third group $262,00.

Another element of enterprise capital is tool and machine capital.

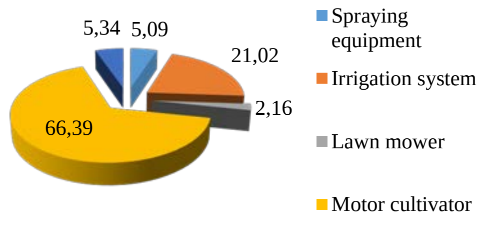

Figure 7. Proportional distribution of tool and machine capital in surveyed enterprises (%)

In the examined enterprises the tool and machine capital asset per enterprise is $1,251.31. The largest share in the formation of the tool and machine capital of the enterprises is the motor cultivator (66.39%). This is followed by irrigation systems (21.02%), lawn mowers (5.34%), spraying equipment (5.09%) and string timmers (2.16%). Tool and machine capital for the first examined group is $1,076.64, for the second group $1,358.87, and for the third group $1,932.22.

Passive capital

Passive capital consists of total foreign capital and equity capital used in the enterprises. The land values held in the lease on the active capital are also included in the passive capital as debts. An enterprise's assets can be financed by two types of sources: foreign sources and equity. Foreign resources are short-term or medium-term and long-term debts obtained from persons or organizations other than business owners (meaning they are borrowed from outside). Equity on the other hand, refers to the financial share of business owners in the business or the size of the risk they have on the business (Acar, 2003).

The equity capital of the examined enterprises is equal to the active capital. The landslides and floods that his the surveyed area in 2014 had a significant impact on the willingness to take out loans and other forms of borrowing. The enterprises also consist of small family businesses that try to finance everything with their own means and provide additional income by working outside of the agricultural season. It is also useful to know that the interest rates for agricultural producers in Bosnia and Herzegovina are quite high. Small agricultural producers can only access credit through micro-credit institutions, with current interest rates at 20.80% for loand up to 42 months.

4. CONCLUSIONS

According to the results of the study, the average amount of the active capital in the enterprises in Zeljezno Polje, where the raspberry production was examined, was determined as $19,179.93. When the average of the examined enterprises is calculated, the three capital elements with the highest share in active capital are building capital (48.29%), land capital (20.47%), and material and supply capital (15.98%) respectively. Since the enterprises are small family enterprises, the tool and machine capital was found to be low. The equity capital of the examined enterprises is equal to the active capital. At the time of the study no enterprise used foreign capital. This shows that the enterprises are traditional family enterprises and states that they avoid borrowing. For this reason, providing access to finance for especially the government, private sector, cooperatives and non-governmental organizations to strengthen raspberry enterprises and enable them to use the developing technology in their businesses (such as cold storage, product drying, processing, etc.) and needs to be facilitated.

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REFERENCES

[1]. M. Acar, Tarimsal Isletmelerde Finansal Performans Analizi, Erciyes Universitesi Iktisadi ve Idari Bilimler Fakultesi Dergisi, 20, 21-37, 2003.
[2]. A. F. Acil, R. Demirci, Tarim Ekonomisi Dersleri, Ankara Universitesi Ziraat Fakultesi, 1984.
[3]. Anonim Kreditni kalkulator - Jednostavno do kredita - EKI Mikrokrediti, 2023.
[4]. Anonim Vodic-za-izvoz-voca-i-povrca-u-EU.pdf (fmpvs.gov.ba), 2016.
[5]. Bećirspahić, D., Kurtović, M., Drkenda, P., Skender, A., Aliman, J., Morfološke karakteristike proizvodnog sortimenta maline na području Bosne i Hercegovine, 49th Croatian and 9th International Symposium on Agriculture, Dubrovnik, Croatia.
[6]. Erkus A., Bulbul M., Kiral T., Acil AF., Demirci R. Tarim ekonomisi. Ankara Universitesi Ziraat Fakultesi Egitim Arastirma Gelistirme Vakfi Yayinlari. Ankara, 1995.
[7]. Erkus, A., Ankara ili Yenimahalle Ilcesinde Kontrollu Kredi Uygulamasi Yapilan Tarim Isletmelerinin Planlanmasi Uzerine Bir Arastirma, A.U. Ziraat Fak. Yayin No:709, Ankara, 1979.
[8]. FAO, (Food Agricultural Organization), FAOSTAT, 2023.
[9]. Hadžić, S., Biltern ROLEND, Udruženje poljoprivrednika „Proizvođači maline-kooperanti“, Žepče, Željezno Polje, 2013.
[10]. Inan, I. H., Tarim Ekonomisi Kitabi, Hasat Yayincilik, III. Baski, Tekirdag, 1994.
[11]. Kljajić, N., Production and export of raspberry from the Republic Serbia, Ekonomika, vol. 63, April-June 2018, No.2, p:45-53.
[12]. Kurtović, M., Maličević, A. (2006), Uzgoj maline i kupine, Poljoprivredni fakultet Sarajevo, p. 3-7.
[13]. Oguz C., Bayramoglu Z., Tarim Ekonomisi Kitabi, Atlas Kitapevi, Konya, 2014.
[14]. Oguz C., Karakayaci, Z., Tarim Ekonomisinde Arastirma ve Ornekleme Metodolojisi, Atlas Kitapevi, Konya, 2017.
[15]. Paszko, D., Pawlak, J., Wroblewska, W., Seasonal Fluctuations in Berries Production in Poland and in the World, Scientific Journals of the Warsaw University of Natural Sciences, Problem of World Agriculture, vol. XVI (31), p. 301-312, 2016.
[16]. Sredojević, Z., Kljajić, N., Popović, N., Investing in Raspberry Production as an Oportunity of Sustainable Development of Rural Areas in Western Serbia, Economic Insights-Trends and Cahllenges, Vol. II (LXV), No. 1/2013, p. 63-72, 201.

REFERENCES

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SARAJEVO BOSNIA & HERZEGOVINA

Net Zero Water Building

Dino Obradović[1], Marija Šperac[2]

Abstract

Water is essential for human life, health and overall well-being, i.e. to reduce poverty and hunger. As day after day the earth's population and the need for water are increasing, whereas the amount of water is decreasing, it is becoming increasingly difficult to satisfy people's water needs. Due to the trend of urban population concentration, it can be said without exaggeration that the functioning of cities will also depend on the quantity and quality of management and distribution of water resources within cities. Drinking water from public water supply system is used in households to cover all types of daily water needs. In order to preserve water as much as possible, in terms of its quality and quantity available for human consumption, an integrated approach to water management is needed. Integral water management is essentially water production and consumption management. Zero-use water building is a building that collects rainwater and recycles its wastewater for reuse, eliminating the need for water supply from public water supply and connection to the sewer network. Appropriately collected and stored rainwater can be used multiple times in dwellings, gardens, yards, parks, for washing public areas, etc. The benefits of rainwater use are ecological and financial. A zero-water building is technologically feasible for existing buildings, but costs are quite high, and various other constraints also arise. This approach is most suitable for new buildings, where space for containers, additional pipelines and filtering systems can be set from the beginning. Zero-water buildings aim to reduce total water consumption, maximise the use of alternative water sources and minimise wastewater discharges from buildings. The paper will present the general concept of zero-water buildings and highlight the importance of water conservation.

Keywords: net zero water building, sustainability, water, water consumption

1. INTRODUCTION

Water is considered one of the basic components of life, and the entire history of mankind and civilization is largely related to it. Water is not only included in the composition of human organism and food, but it is also used to produce food and energy, as well as in industry as a raw material or auxiliary material. Due to its importance for the mankind, supply of water to settlements and the population is nowadays considered to be one of the primary branches of water management. Due to the tendencies of people to concentrate their settlements and themselves as consumers around water, and given the available water resources on Earth, the issue of water supply will become even stricter in the future. The rule of water supply, that every drop of water on the catchment is kept for as long as possible for its wider use, is becoming more and more present in our practice [1]. Only 1% of the total water resources on Earth is drinking water, and as much as a third of water consumed in households goes to flush the toilet that is mixed with faeces to form a substance (mixture) called wastewater [2], [3].

Wastewater is known to be composed of 99.9% water and 0.1% pollution. The primary purpose of wastewater treatment is to prevent infectious diseases and to protect from contamination of groundwater and surface water [4]. The biggest challenge for wastewater treatment is the mixture of human wastewater and factory chemicals with large amounts of water. In combined sewer systems, valuable drinking water is reduced to a carrier of waste substances [5], [6]. One adult is thought to produce about 500 litres of urine [5] –[8] and about 50 kg of faeces [5], [7], [8] over a period of one year. Faeces and urine are resources, not waste, and drainage systems bypass the natural flow of nutrients back into the soil and instead empty nutrients (chemical elements:

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phosphate, nitrogen, potassium, magnesium, etc.) into the water [6]. Looking at this process in which drinking water is used as means of transporting waste materials [9] from the household, it can be seen that there is a double cost (cost of water used and drainage/treatment of wastewater). This is a linear way of thinking [10]. In view of the above, it is important to preserve, manage and recycle water wherever possible.

A growing global population and economic shift towards more resource-intensive consumption patterns means global freshwater use - that is, freshwater withdrawals for agriculture, industry and municipal uses has increased nearly six-fold since 1900 [11]. This is shown in the Figure 1.

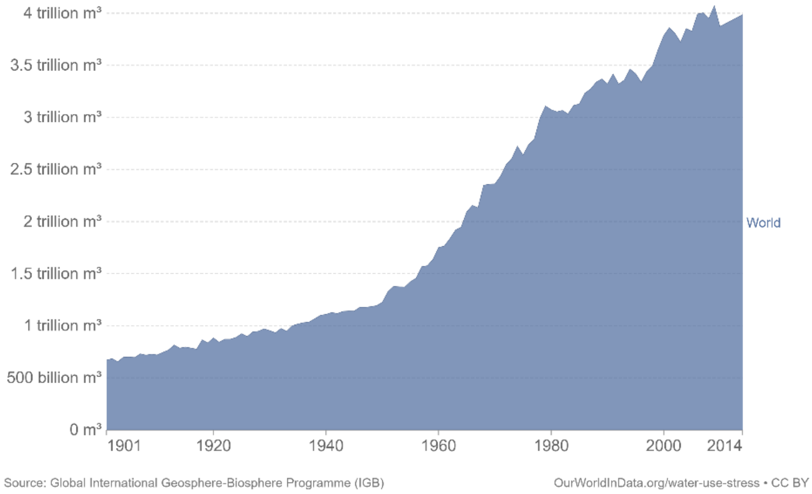

Figure 8. Global freshwater use for agriculture, industry and domestic uses since 1900, measured in cubic metres (m³) per year [11], [12]

People use water for different purposes. It is important to remember that water for different purposes does not have to be potable water. One person per day for survival (drink and food) needs 2.5 to 3 litres, basic hygiene needs 2 to 6 litres, and basic cooking needs 3 to 6 litres leading to a total of 7.5 to 15 litres per person per day for basic emergency needs [13], [14]. Non-drinking water can be replaced by rainwater. So on average, 45 litres of drinking water can be saved each day if replaced by rainwater. Rainwater can be collected on the roof and guided through filters into a container of appropriate size, placed in a suitable place and protected from direct sunlight in order not to start developing algae [15]. The average water consumption in the apartment for one person per day is shown in Table 1.

Table 1. Average daily needs for potable and non-potable water for one person (according to [15])

Drinking water		**Non-potable water**	
Use	**Amount [l]**	**Use**	**Amount [l]**
Shower	35	Toilet flushing	18
Washing dishes	8	Clothes washer	18
Face washing	7	Cleaning	4
Drinking and cooking	3	Watering the garden	5
Total	53	Total	45

The use of water in the household is given in Table 2, and the average daily use of hot water in the household is given in Table 3.

Table 2. Indoor household use [16]

Fixture	**Use [%]**

Table 3. Average daily hot water use per household [16]

Fixture	**Use [%]**

Toilet	24
Faucet	20
Shower	20
Clothes washer	16
Leak	13
Bath	3
Other	3
Dishwasher	2

Shower	39.1
Faucet	33.8
Clothes washer	9.7
Bath	5.7
Dishwasher	4.8
Leak	4.6
Other	2.0
Toilet	0.0

2. LIVING BUILDING CHALLENGE

Water is an important economic resource and the basis for biodiversity, climate and ecosystem regulation. Protecting aquatic ecosystems from pollution and hydromorphological changes and sustainable use of water are essential to meet the needs of the current and future generations, as well as to maintain political stability at national and regional level. The overarching water policy aims to ensure that sufficient amount of quality water is available in the EU for human and environmental purposes by regulating the main pressures (agriculture, industry, municipal wastewater) and water use (bathing water, groundwater, drinking water) and integrated water management. The vast majority of European citizens have access to basic sanitation services and are connected at least to secondary wastewater treatment. In addition, European citizens have high quality drinking water. However, the pressure from urbanisation, diffuse pollution from agriculture, industry and climate change affect water quality and long-term water security. At a global level, the EU promotes water availability, sustainable water management and sanitation for all through the European consensus on development and EU neighbourhood and enlargement policies [17].

The Living Building Challenge - LBC is a certification program that defines the most advanced measure of sustainability - providing a framework for design, construction and the symbiotic relationship between people and all aspects of the built environment. It is one of most rigorous performance standards in the industry, as it requires net-zero energy, waste and water by every project. The LBC is comprised of seven performance areas (Figure 2), or "Petals" - Materials, Site, Water, Energy, Health, Equity, and Beauty [18].

Figure 9. The Living Building Challenge Petals [19]

The petal Water requires net-zero water use which means all of the water used must come from the site. The intent of the petal is to consider water as a scarce resource and helps us think about questions of waste. 100% of water for drinking, cleaning and gardening is collected and treated on site. Rainwater captured on rooftops is purified using ultraviolet light. Low-flow fixtures and composting toilets minimize water demand and used water is treated in sub-surface wetlands. A monitoring system helps building occupants learn about and adjust consumption [19].

Living Building Challenge rewards facilities that achieve net zero water, where 100% of the facility's water use comes from collected sources or closed loop water systems. The impacts of water runoff on the eco system are being considered and whether they are adequately purified without the use of chemicals. Buildings that achieve sustainable water flow where 100% of rainwater and wastewater from the building is managed on site and integrated into a comprehensive system that meets project requirements are analysed as well. In many important facilities in the world, interesting architectural solutions incorporate elements of rainwater collection systems [20].

3. NET ZERO WATER BUILDING

An important water source for net zero water building is rainwater. A significant condition for adequate reduction of the flow of atmospheric waters is the use of water, either for internal purposes, which slows the flow rate, and the water is eventually returned to the catchment through wastewater, or for irrigation which maximizes local evapotranspiration. In suburban housing zones, acceptable reservoir volumes (ca. 2.5 m^3 per 100 m^2 of roof surface) for rainwater collection, which can later be used for a wide range of indoor and outdoor needs, can reduce the runoff of atmospheric waters to almost natural catchment conditions. In multi-dwelling areas with more population and higher potential water needs per unit roof area, the potential to reduce run-off is even greater [21].

An ideal net zero water building uses on-site alternative water sources to supply all of the building's water needs. All wastewater discharged from the building is treated on-site and returned to the original water source [22]. A net zero water building (Figure 3) is a building that collects rainwater and recycles its wastewater for reuse, eliminating the need for water supply from the public water supply and connection to the sewer network.

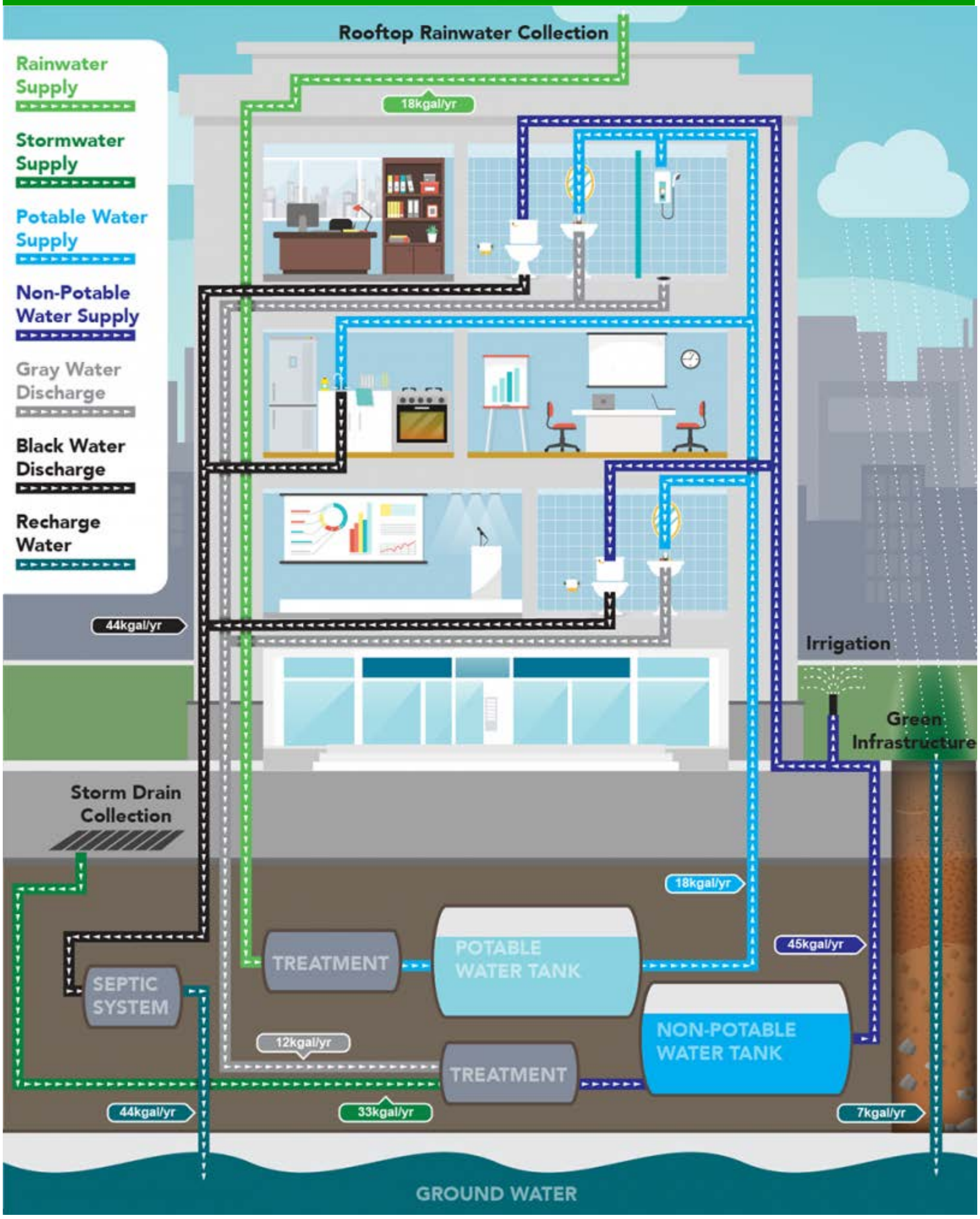

Figure 3. An ideal net zero water building [22]

Net zero water buildings includes the following key design elements:

- Reducing demand by employing innovative technologies that consume less water.
- Producing alternative water sources to offset purchased freshwater.
- Treating wastewater on-site and reuse or inject treated wastewater into the original water supply.
- Implementing green infrastructure by infiltrating stormwater to the original water supply [22].

The goal of net zero water is to preserve the quantity and quality of natural water resources with minimal deterioration, depletion, and rerouting by utilizing potential alternative water sources and water efficiency measures to minimize the use of supplied freshwater. This principle can be expanded to the campus level.

Back in the day, many of the oldest homes could have achieved the net-zero water designations that are cherished today. Rainwater was captured in cisterns, wells provided drinkable water and an outhouse served as a toilet [23].

When talking about net zero water building, it can be achieved gradually, i.e. not every building has to be net zero building, but it is necessary to try to reduce as much water consumption as possible. First, it is necessary to reduce the consumption of water by the householder. In houses, it is necessary to replace old equipment, toilets and appliances that use water, add new toilets that use one quarter of the water of the old ones, and faucets and showers that save water. Water and sewer installations should also be installed in the house to remove leaks, which can be the main source of water loss. All of the above can reduce water consumption by 60% [23].

The next step is to capture rainwater from the roof, just like people did long ago. The rainwater flows into storage tanks – after roof debris is diverted. To make it potable, the water is first filtered, then disinfected by exposure to ultraviolet light. It is ultimately directed to faucets and showerheads within the home [23]. The amount of rainwater that can be collected can be easily calculated. The surface of the roof (flat or pitched) should be calculated and then multiplied by the average annual rainfall. Losses must certainly be taken into account (due to evaporation, absorption, leakage, etc.), leading to a percentage of collected water of 70% to a maximum of 90%.

The most favourable are smooth surfaces, followed by clay covers, artificial substances, or shale. Roofs with rough concrete tiles, bitumen cover and so-called green roofs (flat, grass-covered) are inappropriate. Dust and other impurities are preserved in these roofs. If the roof is covered by a metal cover, it must be calculated with a higher metal content in water, which is therefore less suitable for watering gardens [15].

An example of an underground rainwater storage tank is shown in Figure 4.

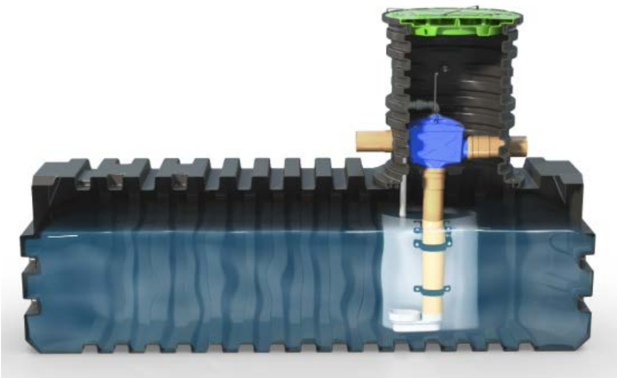

Figure 4. Rainwater harvesting storage tank [24]

Then came analyzing the potential for greywater recycled from sinks and showers to flush toilets. Researchers found that the shower and lavatory would produce slightly more water than the low-flush toilets would need. Extra greywater was dedicated to supplement the needs of the washing machines. One benefit of the greywater system is that potable water from the water company isn't used for toilets, where it isn't really needed. Toilets are the biggest users of water within the home [23].

It is likely that more net zero water homes will only appear in the coming years due to the emergence of a new rigorous certification program, the Living Building Challenge. Unlike green building programs that try to minimize the environmental impact of the house, the Living Building Challenge seeks to eliminate it completely. To earn a certificate, homes must be net-zero in their use of energy and water. Certification is tough because it requires a year's worth of real data, as opposed to a design computation [23].

Certain technologies that can be applied to net zero water building and technologies that can achieve advanced secondary treatment levels to support water reuse or release of less contaminated water back into the environment, taking into account the useful use and appropriate handling of nutrients, are also urine-diversion dehydration toilets - UDDT and urine-diversion flush toilets - UDFT.

Urine can be collected with urinals without water/dry toilets, and the resulting product is natural fertiliser. Faeces can be stabilized by anaerobic method, drying and composting (dry toilets), and biogas and fertilizer are produced as a product. Sanitary water can be purified in wetlands (marshes – artificial/natural), and the resulting water can be used for irrigation. Rainwater does not require any purification and can be directly infiltrated into the soil or collected in containers used for irrigation of agricultural areas [25].

The collection of urine and faeces and water saving can be done in several ways. One way is by using the urin e-diverting flush toilet – UDFT (Figure 5). A urine-diverting dry toilet - UDDT is a toilet that operates without water and has a divider so that the user, with little effort, can divert the urine away from the faeces [26].

Figure 5. The urine-diverting flush toilet (UDFT) [26]

UDDT toilets are mostly used for family houses, schools (in underdeveloped countries), generally not widely used for multi-apartment buildings. The use of UDDT in multi-dwelling buildings is a major challenge. There are only a few examples of UDDT in multi-dwelling buildings in Germany and Mongolia. Faecal tanks are located in the basement and are dimensioned so that a family of five members can use one tank for about half a year. It is recommended to use ashes to cover the faeces. When the first container is filled, the second container shall be used so that the faeces can be sufficiently dried and ready for use [27]. Such toilets are harder to maintain and clean than ordinary toilets (with flushing). Faeces should be covered with sawdust, lime, dry soil, ash to reduce faecal moisture and increase PH due to pathogen extinction [5].

Composting toilets can be integrated into a building’s net zero water strategies with opportunities for maximizing water conservation and reuse. Utilizing composting toilets can result in reduced systems needed for managing a building’s remaining wastewater, including fewer pipes and smaller areas needed for on-site treatment [28].

In the case of waterless urinals, maintenance is simple. A urinal is used only for collecting urine. Urine is stored directly in containers and used later. Tanks can be underground or above ground, depending on the construction and location of the urinal in the building and the type of building. For water-based urinals, the water use per flush ranges from less than 2 l in current designs to almost 20 l of flushwater in outdated models [26].

For household urine, the recommended storage time is 1 to 6 months, depending on the storage temperature (below or above 20 °C). However, if urine is used for its own garden, this is not necessary. Storage time of 1 month is recommended for food and crops under cultivation (e.g. cooking). Six months of storage (if temperature > 20 °C) is required for commercial food production and when raw products are consumed. Urine from public places such as schools or restaurants takes 6 months to store. After this storage time, urine may be used to irrigate all crops (if temperature > 20 °C) [7].

Some of the advantages of the above mentioned technologies of separate collection of human urine and feces at the point of their production are: water savings, organic fertilizer production, energy savings since wastewater contains less nutrients and pathogens and less oxygen is needed during biological treatment, and since less water is in the system, less energy is required to pump water [5].

The lack of separation of urine and faecal matter and non-use of water when flushing toilets is the (non) willingness of people to change habits (people are considered not to be “civilized” if they do not have access to flushing toilets), additional maintenance is needed, the initial costs of such investments are higher, urine is less efficient fertilizer than synthetic fertilizers [5].

All of the above - the separation of types of wastewater and waste materials according to the place of their origin - is advocated by the material flow management method – MFM. The term material flow management covers a broad spectrum of methods and approaches in the literature. In general, material flow management refers to the analysis and specific optimization of material and energy flows that arise during manufacturing of products and provision of services. Material flow management can focus on very different levels of consideration [29]. The path of cross-company material flow management is also described as the product line or product lifecycle, from the input of raw materials, manufacturing, distribution and use consumption up to disposal [29], [30].

4. CONCLUSIONS

Water has always been of great importance and always will be. Preserving its quality and sufficient amount of water should be in our best interests. Climate change and the ever-accelerating urbanisation that causes increasing problems should be driver for a new way of thinking. Integral (sustainable) governance has increasingly been mentioned in all areas of work and life. It is evident that in recent times, much attention has been given to solving the problem of the drainage of atmospheric waters in developed countries, by applying an integral approach to precipitation water planning and management. This is an innovative approach that relies on the environmental principles of drainage planning and design according to the natural way of runoff.

The possibilities of using rainwater in buildings are high. Some of the ways or places where rainwater can be used are to flush toilets, wash clothes, irrigate gardens, etc. The most significant advantage of this approach is its positive influence on the characteristic biophysical features of the urban environment, where the negative effect of rainwater on the urban area is reduced. This approach has many advantages, but is still poorly applied. Changing the existing rainwater drainage systems is quite costly and complex, but nonetheless, the various possibilities and advantages of applying such an approach, its impact on improving the quality of living and housing, improving the protection of space as a whole, and ultimately mitigating the consequences of climate change, are becoming increasingly evident.

Less than 1% of the potable water on Earth is known to be used by humans, among other things (and in large part), to flush toilets. That water is called black water, and actually its only role is to be a transport agent for faeces and urine. Faeces and urine can be used as fertilizer. Of course, certain rules should be observed in such a use. Urine contains most of the nutrients of wastewater, and by volume it accounts for less than 1% of the total amount of wastewater. The separation of urine and faeces, without the use of drinking water as a transport agent, can be done by using water-free urinals, urine-diversion dehydration toilet - UDDT, urine-diversion flush toilet - UDFT where only faeces are rinsed with water and drained and urine is stored in a special tank, etc. A net zero water building (constructed or renovated) is designed to: minimize total water consumption, maximize alternative water sources, minimize wastewater discharge from the building and return water to the original water source. Net zero water creates a water-neutral building where the amount of alternative water used and water returned to the original water source is equal to the building's total water consumption.

The application, i.e. construction of net zero water building, finds many obstacles. Legal barriers - the complexity of managing the regulatory system around such systems at local, state and national level is the biggest obstacle for project teams seeking approval for net zero water projects. Currently, water is regulated in several jurisdictions and agencies. Financial barriers are then emerging as net zero water projects rely on local or distributed water supply and purification systems which are otherwise operated at municipal level by publicly owned utility companies. As such, the burden of costs for supply and processing systems - as well as their current operation, maintenance and replacement needs - is shifted from the utility company to the individual project. Cultural barriers and public perception of the safety of water reuse and on-site management of wastewater pose significant obstacles to net zero water projects. Such fears have roots in our historical management of water and waste and the resulting public health problems that have arisen. Today, education requires convincing the public of the safety of modern decentralised water systems and informing them of their environmental, social and economic benefits.

REFERENCES

[1]. S. Milenković, Vodovod i kanalizacija zgrada, treće dopunjeno izdanje, AGM knjiga, Beograd, 2007.
[2]. M. Crnjak. (2007) Kompostni WC: Spasimo svijet prerađivanjem fekalija u hranu za biljke. [Online]. Available: https://www.poslovni.hr/lifestyle/kompostni-wc-spasimo-svijet-preraivanjem-fekalija-u-hranu-za-biljke-41620 (Accessed: 20.03.2023.)
[3]. B. Motik, Tehnologije za održivi svijet, Priručnik za održivo graditeljstvo i gospodarenje otpadnim vodama, EkoSense, Blatuša, 2009.
[4]. J. N. Počuča, Ekohidrologija, Zagađenje i zaštita voda, Građevinska knjiga, Beograd, 2008.
[5]. Đ. Mak, Održivo upravljanje otpadnim vodama: primjeri i rješenja iz prakse, 2012., [Online]. Available : http://www.obnovljivi.com/pdf/PDF_OBNOVLJIVI_COM/URH_T4_3.Dukan_Mak_Prezentacija_Vol_2.1.pdf (Accessed: 20.03.2023.)
[6]. L. Runko Luttenberger, "Prilog uspostavi decentraliziranih sustava otpadnih voda", Pomorski zbornik, vol. 40, no. 1, pp. 553-560, 2002.
[7]. S. Deegener and M. Samwel, Suhi toaleti, Principi, upotreba i izgradnja, Priručnik za dizajn, građenje, rad i održavanje, WECF- Women in Europe for a Common Future, 2015.
[8]. E. Roma, K. Philp, C. Buckley, S. Xulu and D. Scott, "User perceptions of urine diversion dehydration toilets: Experiences from a cross-sectional study in eThekwini Municipality", Water SA, vol. 39, no. 2, pp. 305-312, 2013., http://dx.doi.org/10.4314/wsa.v39i2.15
[9]. A. T. Larsen, I. Peters, A. Alder, R. Eggen, M. Maurer and J. Muncke, "Re-engineering the toilet for sustainable wastewater management", Environmental Science & Technology, vol. 39, no. 9, pp. 192-197, 2001.
[10]. F. Šrajer, A. Suić, H. Vidović, S. Kipson and H. Carić, Mediteranska kamena kuća, korištenje u skladu s okolišom, energije, otpad, sanitarije, Institut za turizam, Zagreb, 2006.
[11]. Our World In Data, Global freshwater use, [Online]. Available: https://ourworldindata.org/water-use-stress (Accessed: 31.03.2023.)
[12]. Global International Geosphere-Biosphere Programme (IGB), [Online]. Available: http://www.igbp.net/globalchange/greatacceleration.4.1b8ae20512db692f2a680001630.html (Accessed: 31.03.2023.)
[13]. World Health Organization, WEDC: Technical notes on drinking water, sanitation and hygiene in emergencies, July 2013.
[14]. Republika Hrvatska, Vijeće za vodne usluge, Izvješće o radu vijeća za vodne usluge za 2017., Zagreb, prosinac 2018.
[15]. T. Vrančić, "Građevni sustavi", Građevinar, vol. 61, no. 12, pp. 1207-1210, 2009.
[16]. Water Research Foundation: Residantal End Uses of Water, Version 2, executive report, 2016.
[17]. Europska komisija, Dokument za razmatranje o održivoj Europi do 2030., 2019.
[18]. T. Park. (2020) Understanding the Living Building Challenge and Its "Petals", [Online]. Available: https://www.hourigan.group/blog/understanding-living-building-challenge-petals/ (Accessed: 22.03.2023.)
[19]. Williams College. The Living Building Challenge (LBC), [Online]. Available: https://env-center.williams.edu/a-living-building/ (Accessed: 22.03.2023.)
[20]. D. Obradović, M. Šperac and Ž. Koški. "Upotreba kišnice u zgradama", Hrvatska vodoprivreda, vol. XXVII, no. 228, pp. 77-79, 2019.
[21]. D. B. Milićević, N. Lj. Anđelković and M. P. Mitić. "Nužnost integralnog pristupa planiranju i upravljanju atmosferskim vodama na primeru grada Pirota", Tehnika - kvalitet ims, standardizacija i meteorologija, vol. 15, no. 6, pp. 1065-1072, 2015.
[22]. Office of Energy Efficiency & Renewable Energy, Net Zero Water Building Strategies, [Online]. Available: https://www.energy.gov/eere/femp/scenario-1-ideal-net-zero-water-building (Accessed: 22.03.2023.)
[23]. House Plans, Zonda Media, Net-Zero Water Use Demonstration House, [Online]. Available: https://www.houseplans.com/blog/net-zero-water-use-demonstration-house (Accessed: 30.03.2023.)
[24]. Kingspan, Klargester AquaHarvest Domestic Rainwater Harvesting, Available: https://www.kingspan.com/gb/en/products/water-management/rainwater-harvesting/gamma-rainwater-harvesting-solution/ (Accessed: 30.03.2023.)
[25]. M. Šperac and D. Obradović. "Primjena metode "Material flow management" na upravljanje otpadnim vodama" Naučno-stručni simpozijum GEO-EXPO 2018 "Geotehnika, stijenska masa, rudarstvo, geo-okolinsko i građevinsko inženjerstvo", in conference proceedings, Tuzla: Društvo za geotehniku u Bosni i Hercegovini, 2018. pp. 109-116.
[26]. E. Tilley, L. Ulrich, C. Luthi, P. Reymond and C. Zurbrugg. Compendium of Sanitation Systems and Technologies, 2nd revised edition, Swiss Federal Institute of Aquatic Science and Technology (Eawag), 2014., Dubendorf, Switzerland
[27]. F. Meinzinger, M. Oldenburg, A. A. Lisanework, K. Gutema, R. Otterpohl, P. Krusche and O. Jebens. Implementation of urine-diverting dry toilets in multi-storey apartment buildings in Ethiopia, 2009., [Online]. Available: http://www.susana.org/_resources/documents/default/2-1122-en-implementation-of-urine-diverting-dry-toilets-ethiopia-2009-2.pdf (Accessed: 30.03.2023.)
[28]. J. Sisolak and K. Spataro, Toward Net Zero Water: Best Management Practices for Decentralized Sourcing and Treatment, Cascadia Green Building Council, 2011.
[29]. B. Wagner and S. Enzler, (ed.). Material Flow Management, Improving Cost Efficiency and Environmental Performance, Physica-Verlag Heidelberg, 2006.
[30]. S. Zundel, D. Bunke, E. Schramm and M. Steinfeldt, Stoffstrommanagement - Zwischenbilanz einer Diskussion. Zeitschrift fur Umweltpolitik und Umweltrecht. 1998. pp. 317-340.

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Sustainable Design and Maintenance of Buildings

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Abstract

The world's population is increasing, hence the growing demand for accommodation and the construction of buildings. Therefore, the amount of wastewater is increasing. Natural areas (lawns, arable land, forests, etc.) are being used for building buildings. In this manner, natural surfaces become impermeable, which leads to natural unbalance. As a result, we are witnessing formation of heat islands, an increase in temperature and rainfall runoff into the sewerage system as well as uprising consequences of climate change generally. The construction industry is one of the biggest polluters in the world, but by using sustainable construction it is possible to reduce its negative impact on the environment. The principles of sustainable construction should be applied to all phases of the life cycle of a building: design, construction, maintenance, and removal of the building. In the construction design phase, it is possible to modify the building with a slight increase in cost, which will lower future maintenance costs. It is essential to use materials thoughtfully through construction since people spend a large part of their time indoors. Environmental impact assessment is the basis of sustainable design, construction, use, and disposal of the building. Of course, various social issues involve the health and well-being of building users. We must not forget the economic aspects and total costs of the building. This is where the concept of green construction comes into play. Green building refers to both the structure and the application of environmentally responsible and resource-efficient processes throughout the building's life cycle. Green building also refers to saving resources to the maximum extent, including energy, land, water and material saving, etc., during the whole life cycle of the building, protecting the environment and reducing pollution, providing people with healthy, comfortable and efficient use of space, and being in harmony with nature.

Keywords: design, green building certifications, maintenance, management, sustainability

1. INTRODUCTION

Today, the world has reached an enviable degree of urbanization (on average, about 50% of the population live in cities), but developed regions are far more urbanized than undeveloped areas of the Earth (the proportion of the urban population is twice as high in developed than in underdeveloped countries). Such trends will continue, so the projection of the further development of urbanization indicates that in 2030, 61% of the world's population will be urban, but that the disparity between the developed and the underdeveloped will continue to be maintained, although it can be predicted that it will decrease (by that time, developed regions will have an average of about 82%, and undeveloped only 55% of the urban population, so the ratio from 2000, which was 2:1 in favour of developed regions, will decrease to 1.5:1 by 2030) [1]. When talking about energy consumption, it is observed that the share of urban population is directly proportional to energy consumption (more urban population - higher energy consumption, less urban population - lower energy consumption) [1]. The process of urbanization entails much more changes than just the increase of population in cities. Urbanization of a certain region leads to changes in economic, social, and political structures. The accelerated development of cities leads to a decrease of the ability to provide various services such as energy, education, health care, transportation, and physical security. Further problems caused by urbanization are increased traffic, air and water pollution, destruction of agricultural lands, parks, open spaces, etc. [2]. Given that, present urban spaces

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hold less and less capacity as the time goes by as due to its population growth rate more and more buildings are being built, faster than ever, thus creating skyscrapers of a new generation [3].

Urbanization is also reflected in the construction of buildings. The number of building permits issued can be seen as a good indicator of building constructions. Figure 1 shows the number of issued building permits. In 2021, building permits (in terms of useful floor area, measured in millions of square meters; m²) went up by 15% in the EU (in absolute terms, +52 m²). This growth followed a decline of 8% in 2020, the peak year of the COVID-19 crisis [4].

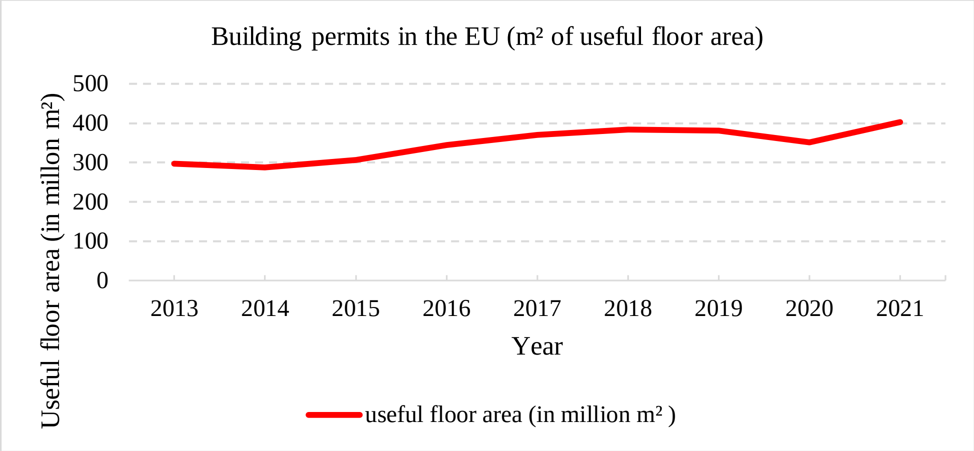

Figure 1. Building permits in the EU, 2015 – 2021 [4]

Today, more than ever, the shortage of resources used in the construction of buildings is emphasized, the number of inhabitants is growing very quickly, and increased urbanization and the construction of new buildings is emphasized. New buildings occupy arable areas or areas that were under greenery, so it is important to think about the maintenance activities of existing buildings, and strive to reduce the construction of new buildings, of course, to the possible extent. It is necessary to use all the resources available to men sparingly and wisely, to build buildings carefully in the sense of paying attention to the types of materials used, the proper execution of the envisioned or designed building, the proper use of the building - use the building for the purpose for which it was designed and built, and finally, when the useful life of the building comes to an end, about the proper disposal of waste from a demolished building [5]. Certain challenges in building management, i.e. building maintenance, are shown in Figure 2.

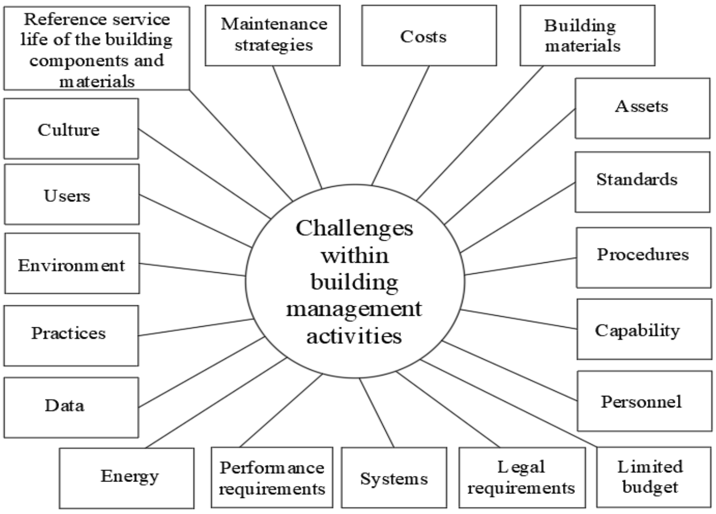

Figure 2. Challenges within building management activities (according to [6])

When it comes to building management, one can see more requirements that need to be met. There are requirements of a limited budget, it is necessary to meet certain standards and there is an increasing number of legal regulations as well as the degree of public acceptance [7]. The impact of construction on the environment takes place throughout the entire life cycle of the building, which includes execution (production of building materials and their installation), use of the building (use and maintenance), and the end of the life cycle (removal of the building) [8]. Buildings play an important role in the energy consumption all over the world. The building sector has a significant influence on the total natural resource consumption and the emissions released [9].

Effective use of natural surfaces, water, energy, and materials should be considered in the design process in accordance with the principles of ecologically sustainable design. Economic difficulties should be considered through the effective use of resources and cost analysis in the context of economically viable design. On the other hand, the quality of life in interior spaces should be increased, and innovative ideas and applications should be applied to a greater extent within the framework of socio-culturally sustainable design [10]. All this leads to the need for sustainable design of buildings and their sustainable maintenance. This issue will be presented in greater detail as we move further along.

2. SUSTAINABLE DESIGN OF BUILDINGS

A sustainable building is a building that incorporates environmentally responsible and resource-efficient practices from planning to design and construction, operation, and demolition to provide a long-term comfortable, healthy, and productive environment for its occupants bringing the negative impact on the surrounding environment to the minimum [11].

By looking at a full life-cycle of a building we can characterize it more specifically. For example, during planning, every impact on the environment should be considered in order to minimize the eventual harmful impact. During the design process architects should make an effort and consider using natural lighting, ventilation, window placement, and all other factors that could save up energy. The construction phase is another good example where we can use natural resources as well as limit energy consumption and proper waste disposal that includes recycling everything that can be recycled. Maintenance is also very important. If the planning is done right, cost of maintenance, energy, and water cost should be very low and used efficiently. Especially by using renewable energy and other resources to operate as a net producer, not just as a net consumer. Demolition is the final stage of the building life cycle. But it’s not the least important. After demolition, it is important to dispose, recycle and handle all materials so they don’t make a negative impact on the environment [11]. The building life cycle is shown in figure 3.

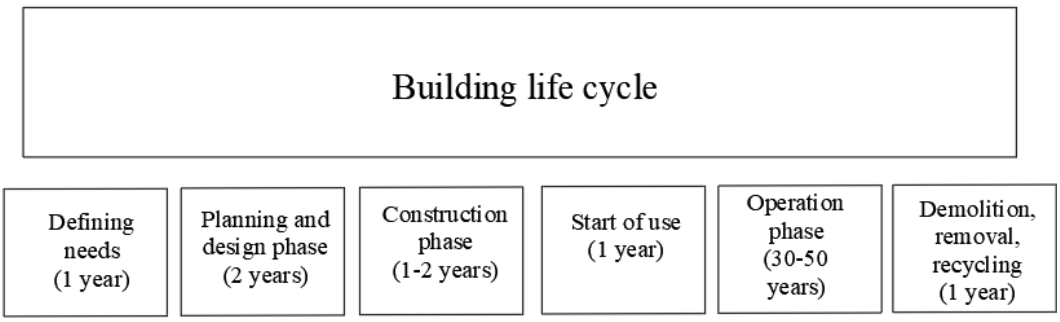

Figure 3. Building life cycle [12]

Sustainable design principles include the ability to:

- optimize site potential;
- minimize non-renewable energy consumption;
- use environmentally preferable products;
- protect and conserve water;
- enhance indoor environmental quality;
- optimize operational and maintenance practices [13].

By knowing all of the above, we can reduce a sustainable design definition by saying that sustainable design not only seeks to reduce a negative impact on the environment, but also to assure the health and comfort of building occupants.

We cannot stress enough how important is good early planning and good building design because it has a major impact on reducing all sorts of costs, pollution and energy used. The sooner sustainable construction is inplemented into the planning, the better. Building Research Establishment Environmental Assessment Method - BREEAM is the world’s longest-running method of assessing, rating, and certifying the sustainability of a building. The BREEAM Assessment investigates different categories such as materials, transport, water, energy, and waste [14].

Five of the green systems that are being utilized in building engineering are radiant floors, gray water recycling, solar power, geothermal systems, and energy-efficient window systems. These systems working together can achieve an owner’s energy and water conservation goals while also reducing utility bills. Sustainable buildings create a win for the environment, the building owner, and its occupants. Radiant floors are an excellent way to efficiently heat a space with less energy. They can contain water tubing that is heated by solar panels that collect solar energy and deliver it to the tubing in the form of heat. Gray water is the water that runs off from condensation from air conditioning units and other equipment that uses water. Unlike wastewater, however, gray water can be reused to fuel boilers, hydronic cooling equipment, and even irrigate plants. With the price of solar panels dropping, solar energy is becoming one of the most cost-effective, as well as practical ways to install a renewable energy source on a commercial building. Geothermal systems are one of the best ways to efficiently heat or cool a building with a renewable source. It uses the naturally cool temperatures below ground to cool water in pipes and then runs it through chilled water coils, just like a chilled water system. It can also be used for heating by a similar process. Windows are responsible for 25% of the heat gain and loss in a building, typically from heat flow through windowpanels and around poorly sealed frames. Energy-efficient windows provide glazing in the form of double panes and triple panes that are designed to inhibit the heat flow. The right window placement is also important for letting in enough light throughout the day to reduce electricity use [15].

And finally, sustainable materials can be explained as materials that have no direct impact on the environment and do not use non-renewable resources [14]. So, by using these materials you can also save money while not having a bad impact on the environment.

Examples of sustainable buildings materials:

- Timber instead of steel
- Concrete reinforced with natural fibers
- Geo-textiles made from crops
- Straws bales
- Materials that are accredited as being responsibility sourced such as the FSC timber [14].

After all, it can be categorized into six basic elements (Figure 4) that need to be investigated when planning and building a sustainable building.

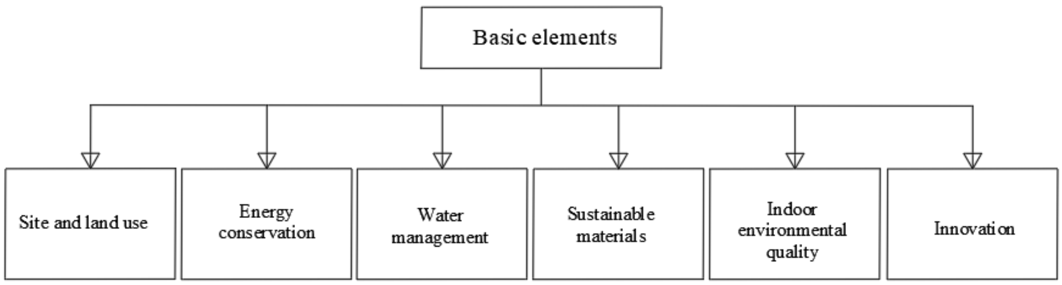

Figure 4. Six basic elements for sustainable building design [16]

Before we start explaining green buildings there is a key difference between sustainable buildings and green buildings. Sustainable buildings operate with all three sustainability pillars in mind (people, planet, and profit), whereas green buildings focus solely on the environment [11].

In green buildings there are four main elements on which it is designed: materials, energy, water, and health to make green building more sustainable [17]. So, materials used for green buildings are always recycled or obtained from natural renewable sources. When talking about energy systems in green building we have to say that the less energy is used the better. The natural daylight is carefully planned so that electricity is reduced to a minimum. Also, carefully planned and placed windows improve people's health and productivity. Speaking of electricity, it is carefully planned to use energy-efficient lighting, low-energy appliances, and renewable energy technologies which can be incorporated by installing wind turbines and solar panels. Even though there are two main differences: Passive solar design and passive solar heating. Passive solar design is transforming the sunlight into heat, also the cooling, as well as providing light to a home. Passive solar heating is based on materials in a building that are absorbing heat for later use or keeping the space inside at a comfortable temperature. We cannot forget about water management in green buildings since it is an important part of the building itself. The main thing is installing greywater and rainwater catchment systems that can recycle water that can later be used to flush toilets, for water-efficient appliances, showers, etc. Health components are also very important. It can be accomplished by using non-toxic materials and products that will improve the life of occupants. These materials are emission-free, have low or no volatile organic compounds (VOC) content, and are moisture-resistant to deter molds, spores, and other microbes. Indoor air quality also cannot be forgotten and it is best accomplished by ventilation systems and materials that control humidity [17].

Even though green buildings seem much more appealing than sustainable design, we must mention that green building can be a part of a sustainable building.

By this we mean a green building cannot be built sustainably, and sustainable buildings can operate without green initiatives. Green buildings can be part of sustainable building design but not the other way around since sustainable design has many more things on its to-do list [11]. So, when thinking about how you can take advantage of the opportunities that sustainability and green initiatives bring, here are a few suggestions:

1) Reduce your energy waste: Small steps such as smart meters, switching to LED lighting, and monitoring water usage and CO_2 levels can make a big difference.
2) Improve your buildings', and occupants' health: You can do this with air quality monitoring, to make sure the building and your occupants are operating at their healthiest.
3) Reduce your environmental impact: Solar and other forms of renewable energy can go a long way in lessening your reliance on fossil fuels.
4) Get certified [11].

Operating as a green and sustainable building benefits all parties involved. Not only are you doing your bit for the planet, but you'll be creating an attractive space for occupants to reside, prolonging the life and health of all those involved [11]. So to sum it all up it can be said that there are "The 7 principles of sustainable construction" (Figure 5).

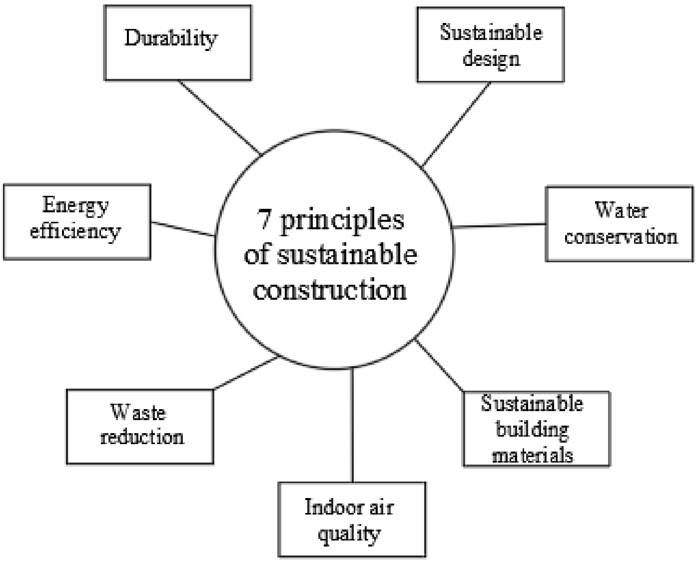

Figure 5. The 7 principles of sustainable construction (according to [14])

For sustainable design, durability, and energy efficiency materials play a big part, prefabricating materials. That is made possible by precutting all materials to the exact length and width in a factory or someplace else. So, when materials are delivered to the construction site there is no additional waste made. Especially because some materials are recyclable on-site. For example, concrete can be crushed and reused for foundations or as aggregate beneath parking lots. The waste made by workers needs can also be reduced efficiently. More and more countries are enforcing the no smoking rule on the site, "walk-off mats" are used to remove dirt, lead, and other potentially dangerous chemicals from their shoes and lunches that are brought in recycling containers for food to decrease organic waste [18].

So not only building is sustainable, but also more and more construction sites are also becoming greener and more nature friendly. The off-site fabrication, improved on-site maintenance, lean practices, landfill avoidance, and green materials acquisition have begun to fundamentally, albeit slowly, transform the way buildings are constructed today as more owners feel a responsibility to build sustainability [18].

3. SUSTAINABLE MAINTENANCE OF BUILDINGS

Building maintenance is an integral part of comprehensive building management. It is defined as undertaking all necessary activities to maintain or improve every part of the building and for the purpose of preserving the value and purpose for which the building or property was built. In order to be able to perform maintenance, it is necessary to analyze the causes of failures, and based on the analysis decide on the measures to be taken to prevent the cause [19].

Although there are many different definitions of building maintenance, the simplest (and probably the shortest) says that building maintenance is ensuring the condition of the building is suitable for use [20]. Of course, it would be very desirable to have a building that does not need to be maintained, but this is difficult to do. To ensure that a building is fit for use, it must be maintained to certain standards. Thus, maintenance costs include all the costs of repairs that occur every day, as well as preventive works and work on improving building elements. These are direct maintenance costs. However, apart from these direct maintenance costs, there are also indirect costs such as fines because the building is not available for use, or it can be a loss of value of the building [20].

The goals of building maintenance are as follows:

- ensuring the security requirements of the building and associated services
- ensuring the suitability of the building for use

- ensuring that building requirements are met regarding legal regulations
- performance of necessary maintenance work to preserve the value of the property
- performing the necessary maintenance work to preserve the quality of the building [21].

We can also say that building maintenance includes tasks such as cleaning, landscaping, and electrical system maintenance. It is needed to preserve a safe, functional, and comfortable environment for tenants at all times. However, most individuals give little thought to the behind-the-scenes work required to meet these expectations. Maintenance is “out of sight, out of mind” until something goes wrong. Maintenance can be categorized as routine maintenance, preventive and corrective maintenance. Running an effective program can streamline maintenance activities and save costs (using CMMS software for example). Property owners and managers rely on building maintenance to ensure functionality, comfort, and safety for occupants.

4. SUSTAINABLE BUILDING CERTIFICATION SYSTEMS

Assessment and certification systems have been developed to quantify the level of sustainability of buildings. During such evaluation, parameters such as space design, construction, and use are observed, and the certificate itself ultimately provides building owners and users with information about the energy and other ecological properties of the building, depending on the type of certificate. Namely, some certification systems cover only certain criteria of building sustainability, such as energy efficiency, and some cover the entire approach to green building, looking at criteria such as location sustainability, human and environmental health, material selection, ecological quality of the interior, social impact and building economy. For each criterion, there is one or more quality criteria that must be proven in order to receive a certain number of points, i.e. meet the requirements [22].

Rating systems have been developed to measure the sustainability level of Green Buildings and provide best-practice experience at their highest certification level [13]. Federal government agencies in the United States, among other things, requires:

1) Reduce portfolio-wide Scope 1 and 2 greenhouse gas (GHG) emissions (onsite combustion and purchased energy) by 65% by 2030, compared to a 2008 baseline.
2) Use 100% carbon pollution-free electricity on a net annual basis by 2030.
3) Pursue building electrification strategies in conjunction with carbon pollution-free energy, efficiency, and space reduction/consolidation.
4) Design new construction and modernization projects greater to be net zero ready (able to achieve net-zero operational emissions) by 2030.
5) Move toward net-zero emissions from Federal procurement, including through a Buy Clean policy promoting the use of construction materials with lower embodied GHG emissions [13].

The Sustainable Facilities Tool is a online resource to support decision-making regarding sustainable building principles, materials, and systems. The Sustainable Facilities Tool helps users understand and select environmentally preferable solutions for renovations, alterations, and leases [13].

The code for sustainable homes is the national standard for the sustainable design and construction of new homes. It aims to reduce carbon emissions and promote higher standards of sustainable design above the current minimum standards set out by the building regulations. The code provides nine measures of sustainable design: energy/CO_2, water, materials, surface water runoff (flooding and flood prevention), waste, pollution, health and well-being, management and ecology. It uses a 1 to 6-star system to rate the overall sustainability performance of a new home against these nine categories. - Code for Sustainable Homes [23].

Table 7. Comparison of different Rating Systems for Sustainable Buildings [24]

Certification systems (Country of origin)	Initiation	Key aspects of assesment	Versions	Level of certification
DGNB (Germany)	2007	- Ecological Quality - Economical Quality - Social Quality - Technical Quality - Process Quality - Site Quality	- Offices - Existing Buildings - Retail - Industrial - Portfolios - Schools	Bronze Silver Gold
LEED (USA)	1998	- Sustainable Sites - Water Efficiency - Energy & Atmosphere - Material & Resources - Indoor Air Quality - Innovation & Design	New Construction, Existing Buildings, Commercial Interiors, Core and Shell, Homes, Neighborhood Development, School, Retail	LEED Certified LEED Silver LEED Gold LEED Platinum
BREEAM (Great Britain)	1990	- Management - Health & Well-being - Energy - Water - Material - Site Ecology - Pollution - Transport - Land consumption	Courts, EcoHomes, Education, Industrial, Healthcare, MultiResidential, Offices, Prisons, Retail	Pass Good Very good Excellent Outstanding
CASBEE (Japan)	2001	Certification on the basis of building environment efficiency factor, BEE=Q/L Q … Quality (Ecological Quality of buildings); L … Loadings (Ecological effects on buildings)	-	C (poor) B B+ A S (excellent)
Mingerie (Switzerland)	1998	4 Building standards are available: (1) Minergie (2) Minergie-P	-	Minergie Minergie-P Minergie-Eco

		(3) Minergie-Eco (4) Minergie-P-Eco		Minergie-P-Eco
Green Star (Australia)	2003	- Management - Indoor Comfort - Energy - Transport - Water - Material - Land Consumption & Ecology - Emissions - Innovations	- Office – Existing Buildings - Office – Interior Design - Office – Design	4 Stars: ‚Best Practice‘ 5 Stars: ‚Australien Excellence‘ 6 Stars: ‚World Leadership‘

CONCLUSIONS

Climate change and increasingly rapid urbanization are causing a growing problem, which should be the trigger for a new way of thinking. Integral (sustainable) management is being mentioned more and more in all areas of work and life. Urbanization has reached large proportions. Large-scale urbanization entails various consequences such as increased traffic, air and water pollution, destruction of agricultural land, parks, and open spaces, and increased building construction. An indicator of building construction can be the number of issued building permits (in terms of useful floor area). In the European Union, there is an increase concerning this indicator. The increased construction of buildings also increases the impact of climate change. Buildings play a major role in the total energy consumption, so attention should be paid to choosing a suitable (sustainable) way of supplying energy and water. An example of efficient use of water is net zero water buildings, where such a building collects rainwater and recycles its wastewater for reuse, eliminating the need for water supply from the public water supply and connection to the sewage network.

All available resources must be carefully used when building new buildings, as well as when maintaining the existing ones. Effective use of natural surfaces, water, energy, and materials should be considered in the design process in accordance with the principles of ecologically sustainable design. The same applies to the maintenance of the buildings. Materials used for the maintenance should be environmentally acceptable, and their reuse should be possible. It is important to develop a circular economy model in which the flow of resources and energy is maintained in a closed loop model, aiming the circulation of products in the circular cycle as long as possible. In the circular economy model, among other things, eco-design, advanced technologies, energy efficiency and the use of renewable energy sources stand out. Innovative ideas and applications need to be applied to a greater extent in the case of continuous design and maintenance.

REFERENCES

[1]. S. Bjelajac and D. Vrdoljak, "Urbanizacija kao svjetski proces i njezine posljedice", *Zbornik radova filozofskog fakulteta u Splitu*, Split, (2009/2010), no. 2/3; pp. 3-19., 2009.

[2]. Funkymem. Globalna urbanizacija i njezine posljedice. (2023). [Online]. Available: https://funkymem.com/zones/globalna-urbanizacija-i-njezine-posljedice (Accessed: 04.04.2023.)

[3]. A. Bogdan, "Nova tehnologija pošumljavanja metropola", *Građevinar*, vol. 68, no. 6, pp. 513-519, 2016.

[4]. Eurostat, Building permits up by 15% in 2021. [Online]. Available: https://ec.europa.eu/eurostat/en/web/products-eurostat-news/-/ddn-20221019-1 (Accessed : 28.04.2023.)

[5]. D. Obradović, "Doprinos povećanju učinkovitosti održavanja kanalizacijskih sustava primjenom modela procjene troškova održavanja". Doctoral dissertation, Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, Croatia, March 2023.

[6]. D. Obradović, M. Šperac and S. Marenjak, "Challenges in Sewer System Maintenance". *Encyclopedia*, vol. 3, no. 1, pp. 122-142, January 2023.

[7]. Y. C. Wijnia and P. M. Herder, *The state of Asset Management in the Netherlands*, in Engineering Asset Lifecycle Management, D. Kiritsis, C. Emmanouilidis, A. Koronios, J. Mathew, (Eds). Springer, London, pp. 164–172., 2010.

[8]. M. Dubraja and N. Mikulić, "Pregled sustava održive gradnje: LEED, BREEAM, DGNB", *POLYTECHNIC & DESIGN*, vol. 6, no. 1, 2018.
[9]. A. Sharma, A. Saxena, M. Sethi, V. Shree and Varun, "Life cycle assessment of buildings: A review", *Renewable and Sustainable Energy Reviews*, vol. 15, no. 1, pp. 871-875, 2011.
[10]. S. Yavasbatmaz and A. Burcu Gultekin, "Sustainable design of tall buildings", *Građevinar*, vol. 65, no. 5, pp. 449-461, 2013.
[11]. Amtivo Group Limited T/A British Assessment Bureau, What's the difference between green and sustainable buildings? [Online]. Available: https://www.british-assessment.co.uk/insights/whats-the-difference-between-green-and-sustainable-buildings/ (Accessed: 03.03.2023.)
[12]. A. Čaušević and N. Rustempašić, *Rekonstrukcije zidanih objekata visokogradnje*. Sarajevo, Bosna i Hercegovina: Univerzitet u Sarajevu, Arhitektonski fakultet, 2014.
[13]. [Online]. Available : https://www.gsa.gov/real-estate/design-and-construction/design-excellence-program-overview/sustainability/sustainable-design (Accessed: 23.03.2023.)
[14]. BuildPass, The 7 Principles of Sustainable Construction (2021) [Online]. Available: https://buildpass.co.uk/blog/the-7-principles-of-sustainable-construction/ (Accessed: 02.04.2023.)
[15]. VIP Structures, 5 Examples of Green Building in Engineering, [Online]., Available: https://www.vipstructures.com/5-examples-green-building-engineering/ (Accessed: 03.04.2023.)
[16]. M. H. M. Zin, and N. L. N. Ibrahim, "Six Basic Elements For Sustainable Building Design", *Australian Journal of Basic and Applied Sciences*, vol. 6, no. 13, pp. 5-10, 2012.
[17]. Elements or Components of Green Building-Material, Water… [Online]. Available: https://theconstructor.org/building/elements-of-green-building/5375/ (Accessed: 16.03.2023.)
[18]. J. Lombardo, For Construction Pros.com, 5 Techniques for Sustainable Building Construction, https://www.forconstructionpros.com/business/article/12068798/five-techniques-for-sustainable-building-construction (Accessed: 02.04.2023.)
[19]. D. Vugrinec, *Facility Management Handbook* - Priručnik za upravljanje poslovnim zgradama. Zagreb: 2G2E - Udruga za gospodarenje građevinama, energijsku efikasnost, promicanje znanja i vještina, 2012.
[20]. M. A. El-Haram and M. W. Horner, "Factors affecting housing maintenance cost", *Journal of Quality in Maintenance Engineering*, vol. 8, no. 2, pp. 115–123, 2002.
[21]. S. Marenjak and H. Krstić, "Analysis of buildings operation and maintenance costs", *Građevinar*, vol. 64, no. 4, pp. 293–303, 2012.
[22]. T. Dokšanović, M. Farkaš and N. Njegovanović, "Tržišna prihvatljivost građevinskog materijala s malim udjelom ugljika - Dio II: Zakonodavni okvir", *Electronic Journal of the Faculty of Civil Engineering Osijek-e-GFOS*, no. 6, pp. 1-12, 2013.
[23]. IEA, Code for Sustainable Homes, (2019), [Online]. Available: https://www.iea.org/policies/397-code-for-sustainable-homes (Accessed: 03.04.2023.)
[24]. M. Bauer, P. Mosle and M. Schwarz, *Green Building - Guidebook for Sustainable Architecture*, Stuttgart, Germany: Springer, 2007.

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Carbon Footprint Estimation In Road Construction: Case Study of Karaman-Mersin

Gizem Aytac[1], Zeynep Eren[2]

Abstract

There are two main methods to combat climate change reduce the effects or stop it, even to avoid worst-case scenarios; moving to on low carbon economy and protecting forests, meadows and pastures, which are the most effective natural sinks in the fight against climate change for that reason. It is an urgent necessity to greatly reduce greenhouse gas emissions and reduce the carbon footprint of every segment, from individuals to sectors and cities in order to minimize global warming and maintain a sustainable life, it is necessary to calculate the carbon footprint and set a road map to reduce it and to control the sink areas for carbon neutralization. Briefly, the carbon footprint is an estimation and explanation of the damage caused by the greenhouse gas produced in terms of carbon dioxide to the environment. In this study, the calculation of the carbon footprint, the creation of carbon hot spots and the determination of which measures should be taken for carbon reduction in the road construction site, which is one of the most important carbon sources, with a ready-mixed concrete plant and tunnel and viaduct construction activities, and it was also aimed that circular economy with the green energy determined for the applicability of that measures. For this purpose, a road map of the carbon footprint is going to be determined according to the ISO 14064 standard based on the method, coefficient and methods published by internationally recognized institutions such as DEFRA and IPCC, and the footprint of the road construction sector will be calculated and estimated between Karaman and Mersin in Turkey. Accordingly, a roadmap has been set through methods such as carbon reduction, changes in production processes, recycling applications according to the determined hot carbon spots.

Keywords: Construction sector, road construction, greenhouse, carbon footprint.

1. INTRODUCTION

Today, with the development of industrialization and technology, there have been developments in the needs of people. It has become very difficult to meet these needs with natural resources, and this problem has brought many environmental problems to the next level. We can talk about carbon footprint as an accepted environmental problem in the world and in our country.[1] The earth needs a healthy functioning ecosystem, seasons and water cycle. However, while the resources that clean the world are consumed, the emission of gases that pollute the air is constantly increasing. As a result of this cycle, climate change and global warming issues emerge. In fact, we can say that climate change is caused by global warming. If we talk briefly about global warming; It can be defined as the increase in the average surface temperature of the world due to the increase in greenhouse gases released into the atmosphere. The point that should be focused on is that the main reason that triggers the warming is due to the increase in the carbon dioxide ratio in the air. It is an accepted fact all over the world that global warming must be prevented for a sustainable life. Global warming min. It is necessary to control the carbon footprint in order to reduce it to the level and continue a sustainable life.

2. IMPORTANCE OF CLIMATE CHANGE

Climate change refers to changes in weather patterns over a long period of time. According to IPCC reports, it is accepted that climate is changing and resulting hydro-meteorological variations that could cause variations

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in risk from sea level rise, extreme weather and their hazards. The accelerated increase in the greenhouse gases (GHG) concentration in the atmosphere is a major cause for climate change and the result of increasing demand to fossil fuels by human being. The global mean temperature has increased to 0.74 °C during the last 100 years. Therefore, much more attention should be given to climate change adaptation through the new policies and technological developments. Climate change is an important, global issue currently affecting the environment and society in a variety of ways. Climate change plays a role in determining human landscapes and living conditions that can affect both social and economic development. There is an important link between climate change and sustainable development. Sustainable development aims to reduce the effects of climate change affecting the environment and society. [2] Global warming refers to the long-term warming of the planet where the average surface temperature rises by about 1°C (about 2°F) relative to the 1951-1980 baseline (Fig.1). [3]. Climate change refers to a wider range of changes, including rising sea levels, accelerating ice melt, an increase in the number and frequency of extreme weather events, the extinction of some animal and plant species, and an increase in climate-related natural disasters. Like floods, storms, hurricanes and droughts. These are all the results of warming, mainly due to humans burning fossil fuels and releasing greenhouse gases (GHG) into the air. [4].

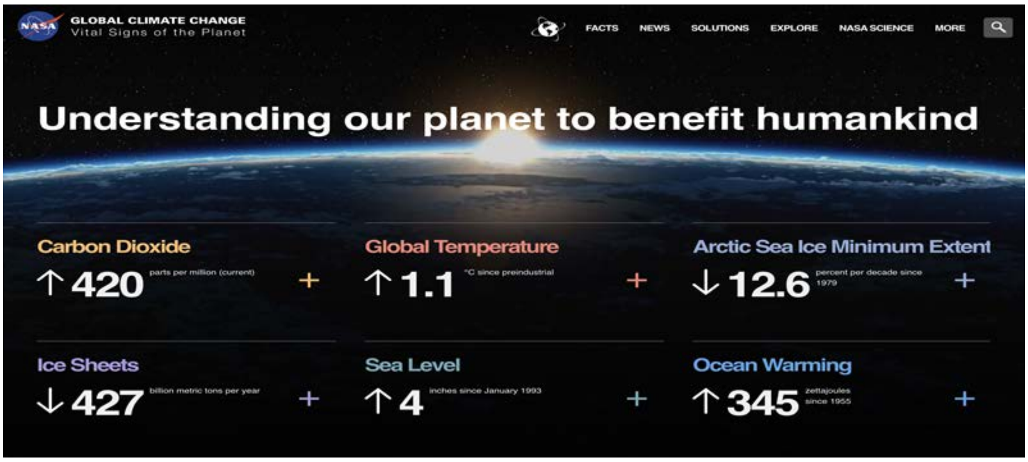

Figure 10: Facts and Figures of Climate Change, NASA 2022

2.1. The Definition of Green House Effect

The greenhouse effect is a process that occurs when greenhouse gases in the Earth's atmosphere trap the Sun's heat. This process makes the Earth much hotter than it would be without an atmosphere. GHGs such as CO_2 CH_4, N_2O and F Gases are added to the atmosphere by various human activities and trap the heat in the Earth's atmosphere by increasing it day by day referring to the global warming [5]. Human activities are changing the Earth's natural greenhouse effect. Burning fossil fuels like coal and oil releases more carbon dioxide into our atmosphere.

2.2. What is the Carbon footprint?

The amount/equivalent of CO_2 emissions released to atmosphere as a result of all human activities or societies is called carbon footprint (Fig.2). Carbon footprint is the calculation of all greenhouse gases, including carbon dioxide, methane, nitrous oxide and fluorinated gases released into the atmosphere as a result of human daily activities, as the gram equivalent of CO_2 (CO_{2e}), which has the highest rate among greenhouse gases. [6]. On a global scale, the main greenhouse gases souced from human activities are: Electricity and Heat Generation, Industry, Agriculture, Forestry and Other Land Use, Transportation, Buildings and other energy sources.

Figure 2: The carbon footprint, CO_2Living

2.*3. Greenhouse Gases*

There are mainly four GHG emission released into the atmosphere: carbon dioxide, methane, nitrous oxide and fluorinated gases (F-gases). Carbon dioxide mainly comes from the fossil fuel burning and can also be released from direct anthropogenic impacts on forestry and other land use, such as deforestation, land clearing for agriculture and soil degradation. Agricultural activities, waste management, energy use and biomass burning are all contributed to methane emissions in the atmosphere. Nitrous oxide is primary emission of agricultural activities such as fertilizer using. And, fluorinated gases come from industrial processes, refrigeration, and the use of various consumer products such as microelectronics. If we look at the sectoral emissions of greenhouse gases; energy sector (electricity, heat and transport) is located as in the first line with the 73.2%, second is agriculture, forestry and land use with 18.4%, third one is the industry with 5.2% and finally waste sector comes at the end with 3.2%.

2.4. Road Construction GHG Emissions

Roads, an important transportation option, emit significant amounts of greenhouse gases throughout their entire life cycle. Large amounts of roads have been built all over the world in recent years, especially in developing countries, and it is estimated that more than 25 million kilometers of new roads will be built by 2050. Carbon emissions of raw materials, especially cement, have a significant impact on the calculation of greenhouse gas emissions from road construction. If it is given an example of the increase in greenhouse gases caused by road construction works around the world, road construction and cement production facilities were identified as the main emission sources in the United States. The cement industry which is the direct CO_2 emission source is an important source of 14.3% of total CO_2 emissions in China [9]. During the life cycle of road projects, the construction phase accounts for the majority of GHG emissions. It has also been shown to consume a lot of resources. Activities such as materials extraction and production, to-site transportation, and construction machinery generate emissions that account for 5% to 25% of the total emissions from road transport during the construction stage. Given the continued high demand for passenger and good transportation, road construction, reconstruction, and expansion are likely to remain a major issue for some time [9].

Figure 3: An example road construction site

3. MATERIAL AND METHOD

3.1. System Boundary

This study calculates the GHG emissions from road construction of ***Karaman-Mersin Road***. The components and steps included within the system boundary for this study are depicted in Figure 4. The system consumes materials and energy and emits GHG which is calculated using both asphalt and cement pavements. The calculation of asphalt pavements includes two major processes: raw material production and pavement construction. The construction process includes the phases of mixing, mixture transportation, laying down, compacting, and curing. The calculation for cement pavements includes three major processes: raw materials production, concrete manufacturing, and pavement construction.

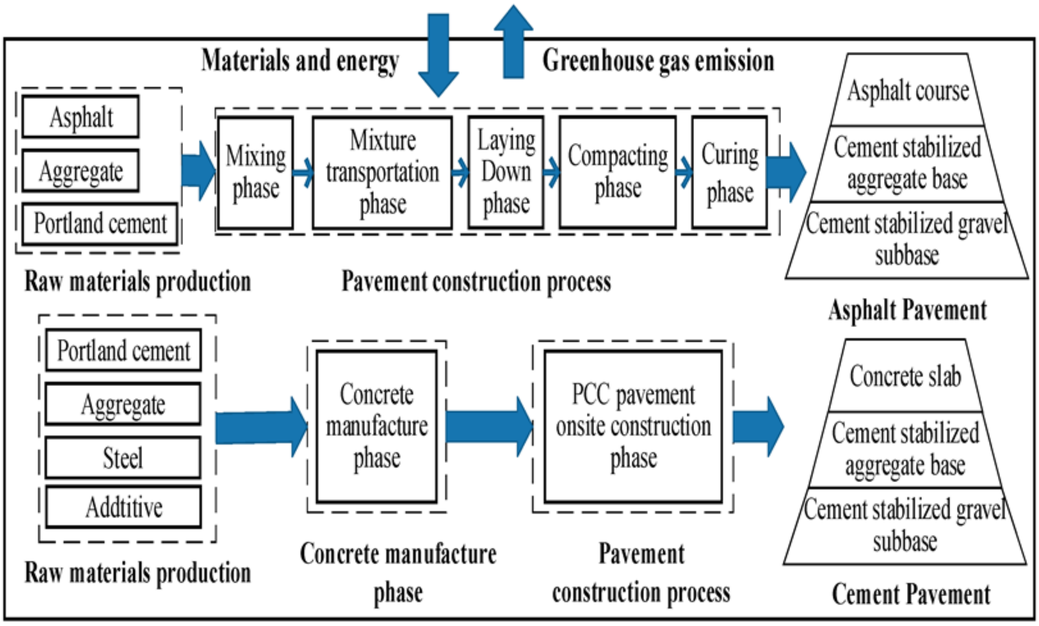

Figure 4: The system boundary of the study

3.2. GHG Data

The GHG includes CO_2, CH_4, and N_2O, which account for 98.9% of carbon emissions from road construction in this study. Global warming potential (GWP) is a widely used characterization method for measuring the impacts of GHG emissions on climate change, and it is used in this work to normalize GHG emissions of these gases by carbon dioxide equivalents (CO_{2e}).

3.3. Calculation of Karaman-Mersin Road Construction GHG Emissions

In this study, calculations are going to make according to the TIER 1 approach based on the emission factors of nationally accepted institutions such as DEFRA and IPCC for the calculation of the carbon footprint in the Karaman - Mersin Road construction site. The equations to be used in carbon footprint calculation are as follows;

- $E_{CO2} = T_E * P_C * EF$
- $E_{CH4} = T_E * P_C *EF = E_{CH4} * G$
- $E_{N2O} = T_E * P_C * EF = E_{N2O} * G$
- T_E = Amount of fuel consumed
- PC= Energy amount of fuel consumed
- EF= Emission factor suitable for the fuel consumed [10].

Since the data received at the facility is based on volume and the process will be based on tons, the volume of diesel fuel must be converted to tons. According to TSE EN 590 standard, the density of diesel fuel is taken as 0.830 gr/lt [11].

Emissions of greenhouse gases originating from flexible and rigid pavement layers of the same length and thickness of the road pavement shoul be calculated using the IPCC methodology. The IPCC implements global climate changes in the world, the negative consequences of climate change on the environment and policies to minimize them. According to IPCC, greenhouse gas emissions are calculated according to the tier 1, tier 2 and tier 3 approaches in the program by using the emission factors and uncertainties in the "National Greenhouse Gas Emission Inventory Report". It is obtained by multiplying the activity data by the factors. Tons are used as the unit of measurement and each greenhouse gas is converted to CO_2 equivalent tons using appropriate GWPs.

4. CONCLUSIONS

In recent years, it has taken many energy-saving and emission reduction measures in the road construction stage, such as warm mix asphalt technology, waste recycling technology, photovoltaic pavement technology, etc., but these technologies are not mature enough [11]. As a result, environmental impacts and GHG emissions from road construction will receive increased attention. Studies have shown us that the most important factor is the fuel consumption factor. For carbon footprint monitoring, carbon emission monitoring was carried out during the material procurement, construction phase, routine maintenance and life cycle. Whatever the result of the work done, the result will be more objective as the work continues in the areas of development, construction, maintenance techniques, demolition and recovery.

However, when the raw material used in road construction is examined in the preparation of road construction, service life, routine maintenance and life cycle, most importantly, taking into account the fuels used for transportation, a completely different picture will be encountered. It is important to reduce the fuel consumption of vehicles used in the transportation sector. Whatever the result of the work done, the result will be more objective as the work continues in the areas of development, construction, maintenance techniques, demolition and recovery. Studies have shown us that the most important factor is the fuel consumption factor [12]. For carbon footprint monitoring, carbon emission monitoring should be carried out during the material procurement, construction phase, routine maintenance and life cycle. For flexible pavement layer and rigid pavement layer, it is considered to be done in the same km and environments, and the carbon footprint tracking of the pavement need to be examined.

REFERENCES

[1]. Yesilyurt, M., 2022. Evaluation of Carbon Footprint in Ready-Mixed Concrete Plant, Master Thesis, Erzurum

[2]. Duran, S. (2022). Climate migration as a new socio-ecological problem (Master's thesis, Hittite University).

[3]. Sen, Z. (2009). Clean energy sources and modeling principles. Water Foundation.

[4]. Somuncu, M. (2018). Is Climate Change a Threat or an Opportunity for Turkish Tourism? TUCAUM 30th Year International Geography Symposium, 748-771.

[5]. Batur, A. (2018). The effect of the greenhouse effect of some gases on the efficiency of solar panels (Master's thesis, Institute of Science and Technology).

[6]. Ozcan, T. Evaluation of carbon footprint in asphalt plant (Master's thesis, Institute of Science and Technology).

[7]. Demir, A. (2009). The effect of global climate change on biodiversity and ecosystem resources. Ankara University Journal of Environmental Sciences, 1(2), 37-54.

[8]. Greenhouse Gas Emissions by Sectors (1990-2020) (TUIK Institutional, 2022)

[9]. Yu C, Wu L, Liu Y, Ye K, Liang G. Estimation of GHG Emissions from Road Construction Taking into account Regional Differences in Carbon Emission Factors of Cement: The Chinese Example. Buildings. 2022; 12(9):1341. https://doi.org/10.3390/buildings12091341

[10]. 2001. Climate change 2001: The scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. Intergovernmental Panel on Climate Change (C. 57). Cambridge, UK. doi:10.1256/004316502320517344

[11]. SE. ,2022. TS EN 590 Automotive fuels - Diesel (diesel) - Requirements and test methods (No: TS EN 590).

[12]. Altinoz, e., & terzi, s. (2020). Karayollarinda ustyapi tipinin karbon ayak izi etkisinin arastirilmasi. Muhendislik Bilimleri ve Tasarim Dergisi, 8(2), 451-459.

Biography

She completed his primary education at Coruh Primary School in Artvin and his secondary education at Artvin Anatolian Teacher High School. He graduated from Ataturk University Environmental Engineering Department in 2015. She completed her master's degree from Trabzon Karadeniz Technical University, Occupational Health Department in 2019. He is continuing his master's degree in the Department of Environmental Engineering - Environmental Technologies at Ataturk University, Institute of Science (2023), and worked as an environmental engineer at the recycling facility between November 2015 and November 2016. Between November 2017 and September 2020, I worked as an environmental engineer and occupational health and safety specialist in the construction of Yusufeli Dam and HEPP.

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The Greywater Footprint Calculation of Erzurum City's Urban Wastewater

Muhammed Selim Ozdemir[1], Zeynep Eren[2]

Abstract

Water is essential for the continuation of human life. Therefore, it becomes important to conduct scientific studies on water management due to the increasing world population day by day, rapidly growing industries, chemical pollution, global warming, drought, etc. The water footprint is one of the methods used to calculate the consumption volume of water directly and indirectly and to manage water resources. Within this context, the concept of water footprint is a pressure indicator developed to reveal how people's choice make about production and consumption affect natural resources. It reveals the pressure on environmental resources how much pollution is caused and how much water is used for our needs in our daily lives. Therefore, this study aims to define a roadmap to calculate the graywater footprint of Erzurum City's domestic wastewater and to show out the pollution caused by the wastewater discharged to the Aras River after being treated in Erzurum Biological Wastewater Treatment Plant.

Keywords: Water footprint, Erzurum Wastewater Treatment Plant, Greywater

1. INTRODUCTION

Climate change is accepted one of the biggest environmental problems of the world, today. According to the report of Climate Change (IPCC) latest summit in September 2013; "Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radioactive forcing, observed warming, and understanding of the climate system." The report also states that human influence has extremely been the dominant cause of the observed warming since the mid-20th century. Therefore, the process can only be reversed through the change of human values and lifestyle, such as the adoption of sustainability [1]. Climate change will be mainly experienced through the water regime and the availability of water resources will be affected by changes in rainfall distribution, soil moisture, glacier and ice/snow melt, and river and groundwater flow [2]. The effects of climate change on major natural disasters such as cyclones, typhoons, floods, landslides have recently attracted significant attention among researchers and the public.

Climate change also affects the oceans. Significant warming of ocean temperatures has been documented on both the east and west coasts of Australia. Such changes are in turn impacting coastal marine ecosystems altering the distribution, growth of marine species, and/or their prey and predators. As a result, marine resource-based industries, such as fishing and aquaculture, are expected to see both opportunities and losses [3]. The other treat could be observed in water and food security under climate change, both are highly vulnerable to this process. The recent studies have shown that the average global temperature may increase by 1.4–5.8 °C and there would be substantial reduction in fresh water resources and agricultural yield by the end of the 21st century [4].

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Water, it is one of the most important needs required for the continuation of its living life. Water forms the major component of a living organism. It plays a vital role as all the metabolic processes required for growth and development requires a liquid medium. Water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival itself. Water and climate change are closely linked. From unpredictable rainfall patterns to shrinking ice sheets, rising sea levels, floods and droughts – most impacts of climate change come down to water. Climate change is elevating both water scarcity and water-related hazards (such as floods and droughts), as rising temperatures disrupt precipitation patterns and the entire water cycle [5]. Only 0.5 per cent of water on Earth is useable and available freshwater and climate change is dangerously affecting that supply. Over the past twenty years, terrestrial water storage has dropped at a rate of 1 cm per year. Therefore, it is important to prevent the pollution of our freshwater sources. Thus, the pollution potential of wastewaters after treatment plant by discharging to the local river is going to be addressed by calculating gray water footprint. In this study, it will be drawn a road map for the defining of gray water footprint of Erzurum Biological Waste Water Treatment Plant.

2. WATER FOOTPRINT

Water footprint (WF) accounting phase of a Water Footprint Assessment quantifies the size, location, and timing of the water footprint of a process, product, producer, or consumer. It accounts for both water consumption volume and pollution, and includes three components. Water footprint (WF) has become an important indicator to track human pressure on the freshwater supply nowadays. The WF was developed in 2002 and The WF concept aims primarily at illustrating the links between water use and human consumption, and between global trade in water and water resources management. It accounts for both water consumption volume and pollution, and includes three components: GREEN, BLUE, GREY (Figure 1).

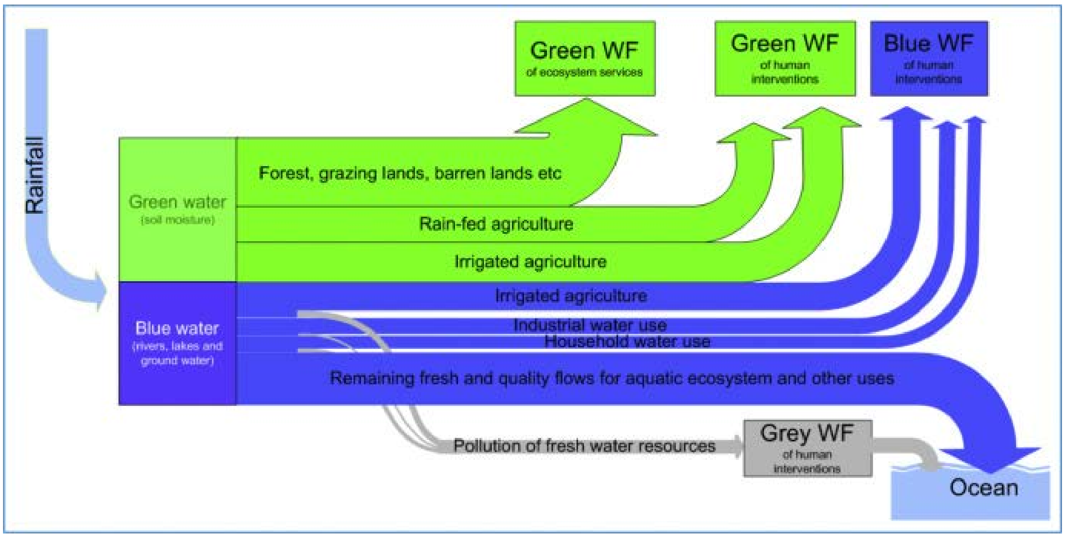

Figure 1. Water footprint components [6]

The BLUE WF is an indicator of the volume of fresh surface or groundwater consumed in producing goods and services. The blue water footprint is the volume of water evaporated, incorporated into the product or returned to a different location or in a different time period from where it was withdrawn. The direct water footprint can include the water footprint of production activities and overheads, for example, the water footprint of offices, canteens, or horticulture.

The GREEN WF is relevant for agricultural and forestry products (products based on crops or wood), where it refers to the total rainfall or soil moisture either evapotranspiration by plants or incorporated into the harvested crop, or both. While, the GREY WF is a measure of pollution and is expressed as the volume of water required to assimilate the pollutant load to meet ambient water quality standards. The pollutant that requires the largest assimilation volume on an annual basis is referred to as the “critical pollutant” and is used to calculate the gray water footprint; if there are both surface and groundwater discharges, the gray water footprint for each discharge is calculated separately.

MATERIALS AND METHODS

All domestic wastewater including small industries and hospital wastewaters of Erzurum City is treated in Erzurum Biological Waste Water Treatment Plant (Figure 2). These wastewaters are passed through biological treatment processes including nitrogen removal and discharged into the Karasu River according to the national discharge criteria. However, the pollution level is increasing and the river's water quality is needed to be analyzed.

Figure 2. Erzurum Biological WWTP, 2022.

COD, total nitrogen, total phosphorus and ammonium, which are the most important parameters showing the pollution in water resources, are important parameters for the gray water footprint. The data will be collected from the Erzurum WWTP for the city gray water footprint calculation (Equation 1-2). The plant operational values for 2021 will be used in the gray water footprint calculations are shown in Table 1. Thus, the river water quality is also going to be analyze and use with the other data for calculating Grey WF.

In the case that pollutanst are part of an effluent discharged into a water body, the pollutant load can be calculated as the effluent volume (Effl, in volume /time) multiplied by the difference between the concentration of the pollutant in the effluent (C_{effl}, in mass / volume) and its natural concentration in the receiving water body (C_{nat}, in mass / volume) . The grey water footprint can then be calculated as follows:

1. $WF_{proc,grey} = L / C_{max} - C_{nat} = Effl \times (C_{effl} - C_{nat}) / C_{max} - C_{nat}$

The pollutant load L is thus defined as the load that comes on top of the natural concentration in the receiving water body. How this equation works out under a number of particular cases is discussed in Box 3.3.

For human-made substances that naturally do not occur in water, $C_{nat} = 0$, so thant :

2. $WF_{proc,grey} = Effl \times C_{effl} / C_{max}$

   This equation can also be used when natural concentrations are not known precisely but relatively low. This assumption gives a overestimated grey water footprint when $C_{effl} < C_{max}$ and an underestimate when $C_{effl} > C_{max}$.

CONCLUSIONS

Water is crucial for the global economy. Yet water scarcity and water-pollution levels are increasing in river basins around the world due to growing populations, changing consumption patterns, and poor water governance. The water footprint is an indicator of humanity's appropriation of freshwater in volumes of water consumed and/or polluted. Therefore, it is to help us know where the water footprint is located, how large that water footprint of a treatment plant is, and whether or not it is sustainable. This is a precursor to identifying priority places to work and providing insight into which strategic actions to take in order to reduce the water footprint of a treatment plant and make it sustainable [8].

It is clear that climate change will affect the economic situation of the world countries unless any measurement can be taken. Therefore, the present study outlines the situation and recommends some measurements to minimize the impact of climate change on the world. First, the most vulnerable regions to climate change should be adapted for strategies to manage climate change risk. Especially, economically feasible techniques and strategies should be formed in the countries. The strategies will vary from one country to other depending on their hydrological conditions. Mitigation of the climate change negative effect can mean using new technologies and renewable energies or changing management politics or operational conditions of treatment plant.

REFERENCES

[1]. Bär, R., Rouholahnejad, E., Rahman, K., Abbaspour, K. C., & Lehmann, A. (2015). Climate change and agricultural water resources: A vulnerability assessment of the Black Sea catchment. Environmental Science & Policy, 46, 57-69.

[2] Fleming A., Hobday A.J., Farmery A., van Putten E.I., Pecl G.T., Green B.S., Lim-Camacho L., 2014. "Climate change risks and adaptation options across Australian seafood supply chains – A preliminary assessment", Climate Risk Management 1, 39–50.

[3] Tezuka S., Takiguchi H., Kazama S., Sato A., Kawagoe S., Sarukkalige R., 2014. "Estimation of the effects of climate change on flood-triggered economic losses in Japan", International Journal of Disaster Risk Reduction 9, 58–67.

[4] Misra, A. K. (2014). Climate change and challenges of water and food security. International Journal of Sustainable Built Environment, 3(1), 153-165.

[5] Zhang Y., Liu F., Wang X., Zhou J., Liu M., Zhang J., Wang W., Li, D., 2014. "The impact investigation and adaptation strategy analysis of climate change on nature reserve in China" Acta Ecologica Sinica 34, 106–109.

[6] https:// figbytes.com/blog/water-footprints-explained/

[7] http://www.eski.gov.tr

[8] Chapagain, A., & Network, W. F. (2010). Water footprint.

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The Pilot Implementation of Deposit Return Scheme In Turkey For Increasing Recycling Rates

Nurdan Tasarsu[1], Zeynep Eren[2]

Abstract

It was conducted an evaluation of the applicability of DRS, which was started to be implemented on a pilot scale in Ankara Province Kizilcahamam District in July 2022 within the scope of the Turkey Deposit Return System Project put into effect by the Ministry of Environment, Urbanization and Climate Change in January 2021, taking into account the domestic waste and zero waste practices based on the 6-month data of the wastes separately collected glass, plastic and metal beverage packaging with DRS. Since 2020, domestic wastes have been separately collected in accordance with zero waste regulation in the region as well. The district was determined as a DRS pilot region in June 2022 as well. For this purpose, deposit return machines (DRM) have been placed at 5 different points in the district center and, the amount of 6-month packaging waste collected from the DRMs until the end of 2022 were used as study data. In addition, the recyclable wastes collected within the scope of zero waste implementations in the district for the last three years and total domestic wastes are also included in the study. It was seen that wastes were collected according to zero waste implementations in 2020, 2021 and 2022 in Kizilcahamam District. The DRS application from July 2022 until the end of December 2022 was found very attractive by the public, and nearly six tons of beverage packaging waste was collected separately in a short period of six months, with a result to almost 6 tons. Considering that organic wastes and construction wastes are included as the recyclable wastes collected separately with the zero waste application, it is evaluated that the DIS application has had a significant success in a short time.

Keywords: Deposit Return Scheme, Zero Waste, Recycling

1. INTRODUCTION

In the solid waste management hierarchy, the most important step after the prevention and reuse step at the source is recycling applications. Recycling is the process of collecting and processing materials that would normally be disposed of as solid waste, transforming them into raw materials and obtaining new products. The collection of waste is seen as the most critical step of the waste management process, but this situation varies greatly according to the development-income level of the countries. While 48% of waste can be collected in urban centers in underdeveloped or developing countries, this rate drops to 26% as one moves towards rural areas. While 96% of waste is collected in developed countries such as Europe and North America, upper-middle-income countries can collect 82%, low-middle-income countries 51%, and low-income countries 39% of their waste [1-2].

In the solid waste management hierarchy, the most important step after the prevention and reuse step at the source is recycling applications. Recycling is the process of collecting and processing materials that would normally be disposed of as solid waste, transforming them into raw materials and obtaining new products.

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Recycling provides many benefits such as protection of natural resources, especially economy, combating climate change, energy saving, land efficiency, waste reduction, reducing/preventing pollution of environmental components such as air, water and soil, and creating new job opportunities. Despite its many benefits, recycling rates are still not at the desired levels in many countries. The main reasons for this are that many people do not have clear information about exactly which materials can be recycled, where and how, and the necessary infrastructure cannot be fully established. It is possible with the Deposit Return Sheme (DRS) to make the recycling rates, which cannot be increased with a voluntary and environmentally friendly approach, attractive with the return of cash [3].

The New Circular Economy Action Plan was adopted on 11 March 2020, as the EU approved the European Green Deal in December 2019. This action plan is seen as one of the building blocks of sustainable growth to achieve Europe's 2050 climate neutral goal and halt the loss of biodiversity. The EU's transition to a circular economy will reduce the pressure on natural resources and create sustainable growth and employment (Figure 1). The new action plan aims to promote circular economy processes, promote sustainable consumption and prevent waste and ensure that the resources used are kept in the EU economy for as long as possible. Among the measures to be taken within the scope of the new action plan, it is aimed to make sustainable products the norm in the EU, to ensure less waste generation by focusing on sectors with high resource use and cyclical potential such as packaging, plastics, textiles, food, water and nutrients [4-5].

Figure 1. Circular Economy Model.

The circular economy model, which is an economy model in which the value of products, materials and resources is preserved in the economy as long as possible and waste generation is minimized; It has become a necessity against the risks of solid waste management such as inefficient use of resources, greenhouse gas and other emissions, depletion of natural resources, difficulty in accessing raw materials, land use limitations and adverse effects on soil and water pollution [6].

Today, when many countries have adopted the circular economy model and started to implement zero waste policies, Deposit Return Systems-DRS (Deposit Return Schemes, DRS) is considered as the most effective and sustainable way to increase recycling rates and not to leave waste to the environment (Figure 2).

Figure 2. Deposit Return Scheme [7]

DRS is a system in which consumers who purchase a product pay an additional amount of money (deposit) and this amount can be recovered by returning the packaging or product to a collection point. Under DRS, producers and consumers agree as parties to a contract: The consumer buys a product with a package, in which case the package, which is a bottle, remains the property of the producer. The consumer returns the packaging to the owner after using the product content. DRS is an application that helps ensure that the packaging is returned to its owner. DRS is becoming an increasingly attractive application system in the world for various packaging wastes collected through containers placed at any point to ensure their reuse or recycling. DRS is seen as the most important tool to reduce packaging waste, but the system still operates on a packaging production. Some large manufacturers also use the "refill" application within the scope of DRS. According to the system that has just started to become widespread in some European countries, the consumer can buy the product again and unpackaged by refilling the products, especially detergents, in the content of the package, which he bought for the first time, at the filling point [8-9].

Therefore, the pilot DRS that conducted in Kizilcahamam, Ankara since the last 6 months of 2022 was investigated in this study.

2. MATERIALS AND METHODS

In order to establish a sustainable, traceable, auditable and controllable system, which can be developed and improved when necessary, the implementation of the projects on a pilot scale is carried out by TUCA before the returnable beverage packages are put on the market. A pilot scale deposit management system was implemented with 4 deposit return machines in the central service building of the Ministry and 5 different point-5 deposit return machines in Kizilcahamam District (Figure 3).

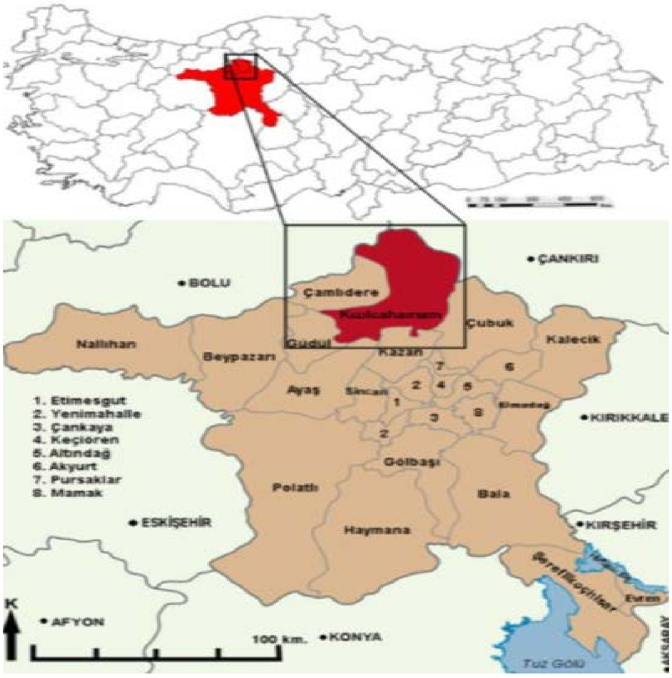

Figure 3. The study area.

The data of the pilot project is followed through the deposit information system, and test studies are carried out before widespread use. Applications called Mobile Application and E-Wallet have been developed for DIS users. With the mobile application installed on the phones from Google Play and AppStore stores, it is possible to log in to the DIS application. After taking the empty beverage packages to any deposit return machine and returning them one by one, the machine issues a receipt to the user (Figure 4). When users show the barcode found on this receipt to their phone's camera via the deposit application, they receive "Tuca" points equal to the number of packages they return, and this score is loaded into their E-Wallet accounts. The earned points can be used for shopping by transferring them to the Ministry Canteen and/or Kizilcahamam Card.

Figure 4. One of the DRS machine in the Kizilcahamam.

3. *RESULTS AND DISCUSSION*:

In this study, within the scope of the deposit project put into effect by the Ministry of Environment, Urbanization and Climate Change in July 2022 in Ankara Province Kizilcahamam District, which was started to be implemented on a pilot scale, it is possible to collect the waste of glass, plastic and metal beverage packaging for 6 months. An evaluation has been made by taking into account zero waste practices (Table 1). DRS is a system where packaging wastes, especially plastic packaging wastes, can be collected separately at a very high rate all over the World. It is seen as an important tool for reducing many packaging wastes such as plastic bottles in the oceans and seas, and it is predicted that it will increase the recycling rates for our country and help achieve recycling targets.

Table 1. Zero waste amount of Kizilcahamam District.

KIZILCAHAMAM MUNICIPALITY ZERO WASTE QUANTITIES, kg				
MONTHS	**2019**	**2020**	**2021**	**2022**
JANUARY	-	40,70	49,96	30,44
FEBRUARY	-	42,70	52,52	38,12
MARCH	-	44,54	65,76	62,74
APRIL	-	42,64	50,85	73,74
MAY	-	41,78	62,78	71,32
JUNE	-	62,48	69,40	74,44
JULY	-	78,28	68,00	67,639
AUGUST	-	83,82	79,18	73,227
SEPTEMBER	-	70,52	71,54	75,506
OCTOBER	-	62,50	62,10	80,601
NOVEMBER	8	57,78	50,06	72,287
DECEMBER	23,98	49,52	59,14	71,711
TOTAL	**31,98**	**677,26**	**741,29**	**803,63**

DRS is a system in which consumers are motivated to voluntarily collect plastic packaging, which has become a huge problem in nature, and other packaging, such as glass and metal boxes, by consumers when they return the packaging to the collection points, and both the infrastructure and the consciousness of the people. It is possible to increase the recycling rates considerably after the basic levels of DRS implementation. DRM will be placed in many social areas, parks, gardens and store centers, especially in shopping malls, with DRS, and an important infrastructure system that combines with digital technology should be established so that consumers can take and return packaging waste to these points. With DRS, which is planned to be spread all over the country in 2023, it is aimed to achieve zero waste targets to a large extent, to increase the amount of separately collected packaging waste, to prevent environmental pollution, to save municipalities on transportation costs, to prevent practices such as sorting garbage on the street and to ensure effective use of sanitary landfills (Table 2). It is expected to make significant contributions to the economy and resource use. The main principles of DRS application; It is necessary to disseminate throughout the country, the material type, size and beverage type of the included returnable beverage packages should be determined correctly and these packages should contain a large part of the total beverage industry, preferably more than 90%.

Table 2. DRS waste amount in Kizilcahamam District.

KIZILCAHAMAM MUNICIPALITY DRS WASTE QUANTITIES, kg															
	Millet Bahcesi Onu			**Sifir Atik Bahcesi**			**Soguksu Milli Parki Girisi**			**Belediye Binasi Onu**			**Cumhuriyet Meydani**		
MONTHS	**G**	**P**	**M**	**G**	**P**	**M**	**G**	**P**	**M**	**G**	**P**	**M**	**G**	**P**	**M**
JULY	0,5	0,03	0,03	-	-	-	-	-	-	-	-	-	-	-	-
AUGUST	34,75	9,9	0,5	-	-	-	77,5	30	0,5	-	-	-	-	-	-
SEPTEMBER	110,5	33,7	1,53	107	27	0,735	324,5	153	4,68	4	10,85	0,255	4,5	11,41	0,645
OCTOBER	164	90	3	965	223	12,7	-	-	-	41	39	2,67	52,5	59,3	7
NOVEMBER	300	217	15	1452	305	16,8	0,25	4,47	0,015	261	156	9,5	632	190	14
DECEMBER	832	431	18	2664	548	21	6,25	4,86	0,09	363	190	5,5	428	163	4,4
TOTAL	**1441,75**	**781,63**	**38,06**	**5188**	**1103**	**51,235**	**408,5**	**192,33**	**5,285**	**669**	**395,85**	**17,925**	**1117**	**423,71**	**26,045**
G. TOTAL	**2261,44**			**6342,24**			**606.11**			**1082.78**			**1566.76**		

CONCLUSION

It is known that every society has its own characteristic structure. For this reason, it is seen that the habits that need to be gained in order to obtain high efficiency from the newly implemented systems should be in accordance with the character structure and behavioral characteristics of the societies. For this reason, during the execution of social awareness and awareness activities specific to the society, in all educational institutions including primary, secondary, high school, university, public institutions, private enterprises, media organs such as social media, radio, television, cafes, restaurants, coffee houses, hairdressers, barbers, beauty salons. Social areas, youth centers, libraries, kindergartens and playgrounds, mosques and places of worship, grocery stores, markets and shopping centers, in short, every area where life activities are carried out should be considered. Collaborating with people loved by all segments of the society in promotional and promotional broadcasts for the dissemination of the DRS application; Raising awareness with various advertisements and public spots in broadcasts with a high audience, especially local governments following the practice closely, taking clear and deterrent measures such as restricting the use of plastic bags, including applicable and deterrent penalties in the legislation for each stakeholder of the system "applicability" principle and ensuring sustainability; It is thought that it will be important both in terms of spreading the practice of DRS and creating zero waste awareness and reducing all other environmental problems.

REFERENCES

[1]. EEA 2011. Recycling industry can boost the European economy, https://www.eea.europa.eu, Access Date, 08.06.2023.
[2]. EU 2020a. Circular economy action plan: The European Green Deal, https://environment.ec.europa.eu/, Access Date: 30.05.2023.
[3]. DRS 2018. Deposit - Return Schemes, Data and figures from 16 member countries of the EPA Network, https://plonesaas.devel4cph.eea.europa.eu/, Access Date: 30.11.2022.
[4]. EEA 2011. Recycling industry can boost the European economy, https://www.eea.europa.eu, Access Date, 08.12.2022.
[5]. EEA 2016.Solid waste, https://www.eea.europa.eu, Access Date: 22.12.2022.
[6]. EEA 2021. Assessing the effectiveness of European waste management policies within circular economy under the EU Green Deal, https://unece.org/, Access Date: 08.08.2022.
[7]. EU 2015. Circular Economy Action Plan 2015, https://ec.europa.eu/, Access Date: 23.06.2022.
[8]. EEA 2022. Waste generation in Europe, https://www.eea.europa.eu, Access Date: 12.12.2022.
[9]. EPA 2022. Recycling in the United States, https://www.epa.gov/, Access Date: 2.11.2022.

Biography

I was born in Yozgat in 1989, after completing my primary and secondary education in Yozgat, I went to Erzurum for my undergraduate education. After completing my undergraduate degree at Erzurum Ataturk University, I returned to my hometown. I have been working as a facility manager at the Medical Waste Sterilization Facility for 7 years.

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Life Cycle Assessment for Sustainable Solid Waste Management in Erzurum City

Kubra Ar[1], Zeynep Eren[2]

Abstract

Waste amount has increased and solid waste management has become an important environmental issue with the increase in population and the change in social living conditions. Therefore, solid waste management is important in terms of controlling environmental impacts. Life Cycle Assessment (LCA) is a method that measures the environmental impact of products or systems throughout their life cycle. Working with a cradle-to-grave approach, LCA starts from raw material supply and continues with production, transportation, consumption and waste generation. Evaluation of products and services throughout their life cycles provides an opportunity to evaluate the environmental impacts of the decisions. The aim of this study is to develop a LCA framework that enables a sustainable solid waste management system for Erzurum city. Thus, it can be developed a road map to reduce environmental pressure caused by solid waste. The solid waste LCA system, which will be implemented for a determined process, consists of the four elements as system boundaries, waste characterization, waste facilities, and environmental impacts.

Keywords: Solid Waste, Erzurum Province, Life Cycle Assessment.

1. INTRODUCTION

Globalization and industrialization increase the amount of waste all over the world. In addition, the increase in urbanization and industrialization necessitates the management of this increase in the respect of amount of waste. In this way, it is possible to create more livable environments and to ensure sustainability. Solid wastes are defined as solid materials that are intended to be disposed of by the manufacturer and that must be disposed of regularly, especially in terms of environmental protection. It is material, which is not in liquid form, and has no value to the person who is responsible for it [1].

It is necessary to ensure that solid wastes are collected, transported, recovered and disposed without harming the environment. Solid waste management is the one thing just about every city government provides for its residents. In this point, it is necessary to ensure that solid wastes are collected, transported, stored and disposed without harming the environment. So, solid waste management is arguably the most important municipal service [2]. While there were about 2.9 billion urban residents who generated about 0.64 kg of MSW per person per day (0.68 billion tonnes per year), this amount has increased to 2.2 billion tonnes per year by 2025 [2]. Managing waste properly is essential for building sustainable and livable cities. Effective solid waste management systems require integrated systems that are efficient, sustainable, and socially supported. One of the big challenges that today's growing cities are coping with is the delivery of effective and sustainable waste management, together with a good sanitation [3].

Life-cycle assessment (LCA) is a process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities. It can be used to study the environmental impact of either a product or the function the product is designed to perform. LCA is commonly referred to as a "cradle-to-grave" analysis. LCA's key elements are: (1) identify and quantify the environmental loads involved; e.g. the energy and raw materials consumed, the emissions and wastes generated; (2) evaluate the potential environmental impacts of these loads; and (3) assess the options available for reducing

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these environmental impacts. The main areas of the application of LCA within public environmental politics are waste treatment options, means of transport, energy sources, and product's choice [4-5].

From this point of view, the aim of this study is to develop a LCA framework that enables a sustainable solid waste management system for Erzurum city. The remainder of this study is structured as follows: Section 2 provides theoretical framework including the background information on life cycle assessment and solid waste life cycle assessment. Then, Section 3 presents the application, followed by Chapter 4 displaying the discussion and conclusions.

2. THEORETICAL FRAMEWORK

2.1. Life Cycle Assessment

Life Cycle Assessment (LCA) is a method that measures the environmental impact of products or systems throughout their life cycle. Working with a cradle-to-grave approach (Figure 1), LCA starts from raw material supply and continues with production, transportation, consumption and waste generation. LCA is a globally used and accepted method for assessing environmental impacts of a product's life cycle from cradle to grave, including all life cycle phases: production, use, waste. It is a computer-based tool used to assess the environmental burden as well as benefits associated with a product or service.

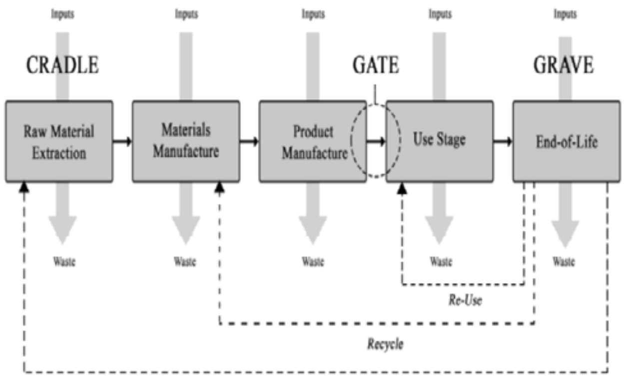

Figure 1. Ecological loop (Cradle-to-Cradle)

LCA has mainly been developed for analyzing material products, but can also be applied to services, e.g. treatment of a particular amount of solid waste [6-7]. LCA can be used for municipal [8-12] and hospital [13-16] solid waste generally.

2.2. Solid Waste Life Cycle Assessment (SWLCA)

Solid waste amount has increased and its management has become an important environmental issue with the increase in population and the change in social living conditions. Planning the waste applications for solid wastes in a way that will not harm the environment is important in terms of managing environmental impacts. Evaluation of products and services throughout their life cycles provides an opportunity to evaluate the environmental impacts of the decisions.

Solid waste life cycle process boundary is the interface between the waste management system and the environment or other product systems as in Figure 2. The life cycle starts once a material or product becomes waste, i.e. its owner discards it in the waste collection bins. Solid waste is collected either via mixed-bags or via separate collection. Each collection method requires its own infrastructure.

The transportation stage follows. In the solid waste management system of developed countries, the mixed bag waste can either go to the landfill, the waste- to-energy facility or to the treatment plant. The source-separated waste, if it is a dry stream, can go to the material reclamation facility or if it is a wet stream can go directly to the biological treatment facility.

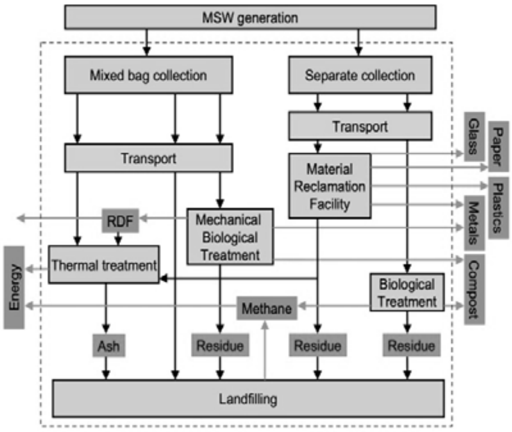

Figure 2. The complete life cycle of municipal solid waste [17]

3. APPLICATION

The SWLCA system, which will be implemented for a determined solid waste management system, consists of the many hierarchical processes. According to it, SWLCA application for solid wastes generated in Erzurum City has been carried out in four elements as *system boundaries, waste characterization, waste facilities,* and *environmental impacts.*

3.1. System Boundaries

The system boundaries of the waste management of Erzurum City determined in the study is shown in Figure 3. According to it, there are five main processes in the application. In the first stage, the produced wastes are collected and transported. There are two alternative ways to transportation of the wastes. In the first of these, the wastes are transferred to the transfer station firstly and then sent to the landfill. In the other alternative, the wastes are sent directly to the landfill. The wastes in the landfill can be sent to the relevant facility for energy production, as well as to the leachate treatment facility.

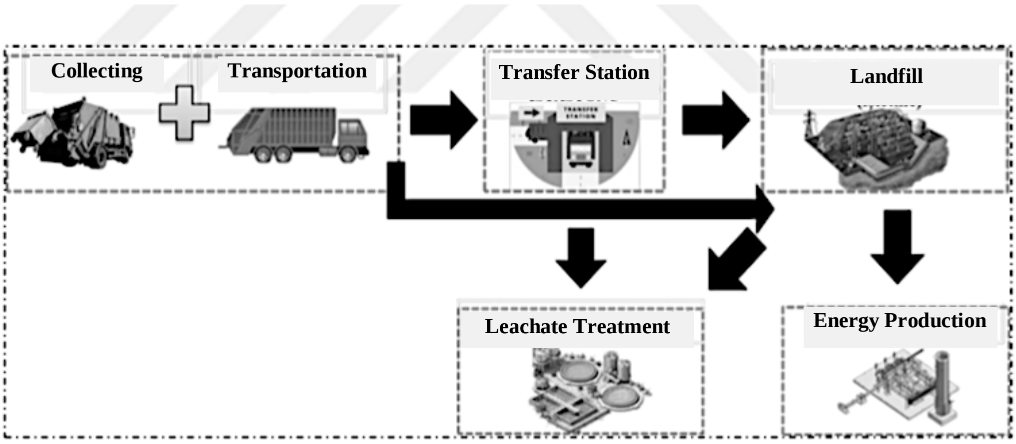

Figure 3. The system boundaries of the waste management of Erzurum city.

3.2. Waste Characterization

In order to carry out the SWLCA application, the waste characterization of the relevant city should be determined. In this context, waste characterization of Erzurum City determined in the study can be seen in Table 1. The waste amount in Erzurum city is 21.600 tonnes per mounth.

Table 1. The Waste Characterization of Erzurum City (%)

		Summer	Winter
Recyclable Wastes	Glass	2,96	2,96
	Metal	1,31	1,31
	Paper / Cardboard	6,80	6,80
	Plastic	10,69	10,69
Other Wastes	Waste Medicine	0,60	0,60
	Vegetable Waste Oil	0,17	0,17
	Waste Battery	0,32	0,32
	Textile Waste	1,00	3,60
	Electronic Products	1,10	0,11
	Bulky Wastes	17,50	17,50
Biodegradable Wastes		56,94	56,94
Total		**100**	**100**

3.3. Waste Facilities

Another important step in SWLCA implementation is to determine the facilities in the waste management system. According to it, waste facilities of Erzurum city determined in the study can be seen in Table 2.

Table 2. The Waste Facilities in Erzurum City

Facility	Amount	Capacity (tonnes/year)
Packaging waste collection separation plant	2	34.483
Recycling plant.	2	6.855
Non-hazardous waste collection separation plant.	14	-
Landfill Plant	2	131.400

3.4. Environmental Impacts

It is very important to determine the scope of the calculations within the SWLCA application. Thus, environmental impacts of the wastes need to be revealed. Therefore, environmental impacts arising from waste managed in Erzurum city on the basis of impact categories presented in Table 3.

Table 3. Environmental impacts of solid wastes in Erzurum city

Global Impacts	• Global warming. • Soil moisture loss. • Forest loss/changes and changes in wind. • Ozone depletion. • Consumption of natural resources – Depletion of natural resources for future generations.
Regional Effects	• Photochemical smog. • Acidification.
Local Effects	• Human health, • Terrestrial toxicity. • Aquatic toxicity. • Eutrophication, Land use – Loss of terrestrial habitat necessary for natural life and reduction in landfills. • Water use – Reduction in existing surface and underground water resources.

4. DISCUSSION AND CONCLUSION

Solid waste management is the one thing just about every city government provides for its residents. So, solid waste management is arguably the most important municipal service. One of the big challenges that today's growing cities are coping with is the delivery of effective and sustainable waste management, together with a good sanitation. The main goal of this study is to develop a LCA framework that enables a sustainable solid waste management system for Erzurum city.

The SWLCA system, which will be implemented for a determined solid waste management system, consists of the many hierarchical processes. This study indicates that there are four main elements of an effective SWLCA application. They are system boundaries, waste characterization, waste facilities, and environmental impacts.

This study has also some limitations. For instance, no numerical analysis was made within the scope of the study. Therefore, similar studies are needed in different empirical contexts to further validate the process. Moreover, the study also cannot provide an estimation about the effect of a SWLCA to be implemented in Erzurum city. Accordingly, further studies are needed to calculate the estimation of an implemented SWLCA model.

REFERENCES

[1]. Zurbrugg, C. (2003). Solid Waste Management in Developing Countries, EAWAG, SANDEC.
[2]. Hoornweg, D., and Bhada-Tata, P. (2012). What A Waste: A Global Review of Solid Waste Management, Urban Development Series Knowledge Papers, The World Bank.
[3]. Reddy, P. J. (2011). Municipal Solid Waste management. The Netherlands: CRC Press/Balkema.
[4]. Finnveden, G. (1999). "Methodological aspects of life cycle assessment of integrated solid waste management systems", Resources, Conservation and Recycling, 26 (3-4), 173-187.
[5]. Ogwueleka, T. (2009). Municipal Solid Waste Characteristics and Management Iin Nigeria, Journal of Environmental Health Science & Engineering, 6(3), 173-180.
[6]. Dixon, N., and Jones, D.R.V. (2005). Engineering Properties of Municipal Solid Waste. Geotextiles and Geomembranes, 23(3), 205-233.

[7]. Cleary, J. (2009). “Life cycle assessments of municipal solid waste management systems: A comparative analysis of selected peer-reviewed literature”, Environment International, 35 (8), 1256-1266.

[8]. Banar, M., Cokaygil, Z., Ozkan, A. (2009). “Life cycle assessment of solid waste management options for Eskisehir, Turkey”, Waste Management, 29 (1), 54-62.

[9]. Gunamantha, M., and Sarto (2012). “Life cycle assessment of municipal solid waste treatment to energy options: Case study of KARTAMANTUL region, Yogyakarta”, Renewable Energy, 41, 277-284.

[10]. Hong, J., Li, X., and Zhaojie, C. (2010). “Life cycle assessment of four municipal solid waste management scenarios in China”, Waste Management, 30 (11), 2362-2369.

[11]. Yay, A.S.E. (2015). “Application of life cycle assessment (LCA) for municipal solid waste management: a case study of Sakarya”, Journal of Cleaner Production, 94, 284-293.

[12]. Iqbal, A., Liu, X., and Chen, G-H. (2020). “Municipal solid waste: Review of best practices in application of life cycle assessment and sustainable management techniques”, Science of The Total Environment, 729, 138622.

[13]. Ali, M., Wang, W., and Chaudhry, N. (2016). “Application of life cycle assessment for hospital solid waste management: A case study”, Journal of the Air & Waste Management Association, 66 (10), 1012-1018.

[14]. Campion, N., Thiel, C.L., DeBlois, J., Woods, N.C., Landis, A.E., and Bilec, M.B. (2012). “Life cycle assessment perspectives on delivering an infant in the US”, Science of The Total Environment, 425, 191-198,

[15]. Khandelwal, H., Dhar, H., Thalla, A.K., and Kumar, S. (2019). “Application of life cycle assessment in municipal solid waste management: A worldwide critical review”, Journal of Cleaner Production, 209, 630-654.

[16]. Kumar, V., Gaurav, G., Khan, V., Choudhary, S., Dangayach, G.S. (2023). “Life cycle assessment and its application in medical waste disposal”, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2022.12.255.

[17]. Abeliotis, K. (2011). Life Cycle Assessment in Municipal Solid Waste Management, in Integrated Waste Management-1, Mr. Sunil Kumar (Ed.), ISBN: 978-953-307-469-6.

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As a Climate Adaption Study, Sea Pollution Arising from Activities in Fishermen's Shelters and Solution Proposals

Ilhame Batur[1], Yuksel Ardali[1]

Abstract

Fishermen's shelters are where fish are not only unloaded from boats and ships but also sorted, processed, packaged, stored, and sold. Fishery products produced in these structures are perishable goods. Therefore, compared to other structures, fishing coastal structures must have specialized amenities and components. Fish waste and oil pose a significant issue in the coastal areas of fishing huts in Samsun. The fishermen's shelters in this area were followed and samples were taken from different areas, the fact that the dissolved oxygen of the sea water drops to almost zero in peak seasons has shown how effective the ecological degradation in that region is. In this study, a solution has been produced for a problem that is easy in practice but ignored, and information will be shared for its application in fishermen's shelters.

Keywords: Black Sea, Fisherman's Shelter, Fisheries Residues, Marine Pollution, Oil/Grease

1. INTRODUCTION

There are various viewpoints on the construction and operation of fishing shelters in several nations throughout the world. These variations varies both nationally and regionally. When dividing them into sizes, the Food and Agriculture Organization of the United Nations establishes the standards for fishermen's shelters. Smaller shelters are prioritized, and their shelters are only used for offshore and coastal fishing. The significance of water, good hygiene, and health regulations are emphasized in this paper [1]. The majority of wastewater from fishermen's huts around the world is, in general, connected to the main network by getting connection approval. Oil, water, and sediments are frequently present in oily ship trash. Non-toxic wastes include fishing nets, plastic items, wet fish waste, bloody and oily fish waterways, and wooden or plastic fish crates. Anchovies and sprats, which are the majority oily fish in the Black Sea, are carried to the fishermen's shelters with the start of the fishing season after being caught by the fishing vessels. The bloody and oily fish waters, which are transferred to fish-booms and truck crates during the transfer of the fishing products carried to the fishermen's shelters by boats, are seen to cover the sea surface as a result (Figure 1.1).

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Figure 1. Discharge of Water into the Sea with Fishboom.

Figure 2. Discharge of Water into the Sea with Fishboom.

In this season, a bloody/oily layer and a bad smell are formed on the surface and disturb the people around. If the amount of fish caught is high, it is exposed to sunlight in the area where it is kept and waste water and bad odor occur with the washing of these fish. The layer consisting of these wastes infects the walls and the beach on the shores of the fishermen's shelters and creates visual pollution and bad odor. In addition, as the bloody/oily water covers the sea surface, the amount of oxygen in the water decreases, and as a result, the living life in the fishermen's shelter decreases (Figure 1.2).

Sorption helps to convert oil from a liquid state to a substance in a semi-solid or solid state, thereby removing oil from the surface of the water. In order for a particular material to be considered a good sorbent, it must have a large surface area, since its sorbing capacity is proportional to its surface area [2]. Sorbent substances are divided into three classes according to their source: natural organic solvent materials, mineral/natural inorganic sorbent materials, synthetic sorbent materials.

2. MATERIALS AND METHODS

Fishing shelters are heavily utilized in the Black Sea due to the multi-fleet nature of the fishing activities. Fish waste and oil on the sea's surface are a major issue in the fishing huts along the Black Sea coast. The Yakakent and Canik Fishing Shelters in Samsun Province, which are listed in Figure 2.1.1, provided samples for this investigation. The samples used in this investigation were collected from Samsun's seashores. Analysis of dissolved oxygen, chemical oxygen demand, oil-grease, nitrogen, and phosphorus were performed on samples of sea water. It is determined that in order to stop this pollution in fishermen's shelters, physical treatment followed by adsorption using adsorbent material, evaluation of the collected oil as biodiesel, and burning of the final wastes in the incinerator facility would be appropriate [3]. In this study, it was discovered that the removal effectiveness of perlite, zeolite, sedge, under-sieve, and bentonite adsorbents was higher.

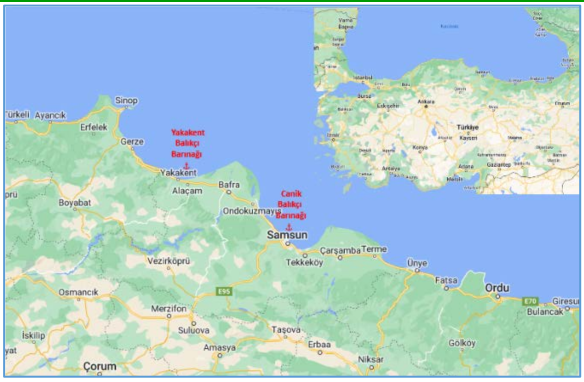

Figure 1. Location of Samsun Province Yakakent and Canik Fishing Shelters Samples from Sea Water.

Studies were conducted on oily sea water samples collected between September and October 2021, just before the start of the hunting season from the Yakakent and Canik Fishing Shelters in the Samsun Province. Figures 2.2 to 2.4 below show the oil concentration and oil removal effectiveness of sea water samples taken from Yakakent Fishing Shelter.

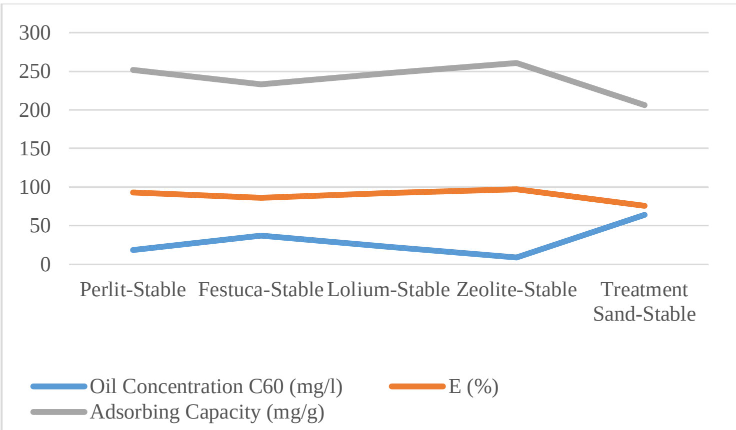

Figure 2. Yakakent Fisherman's Shelter Oil Concentration, Oil Removal Efficiency and Adsorbing Capacity (C_{60}=60.min., adsorbent 0,1 g. C_{o} =270 mg/l).

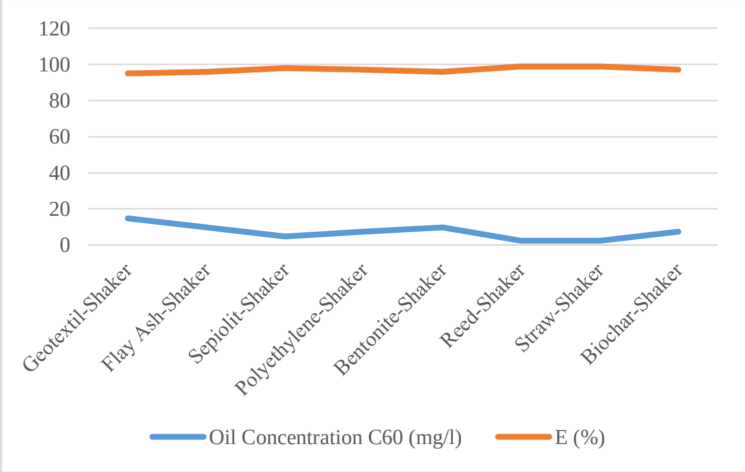

Figure 3. Yakakent Fisherman's Shelter Sea Water Adsorption Studies Oil Concentration and Removal Efficiency.

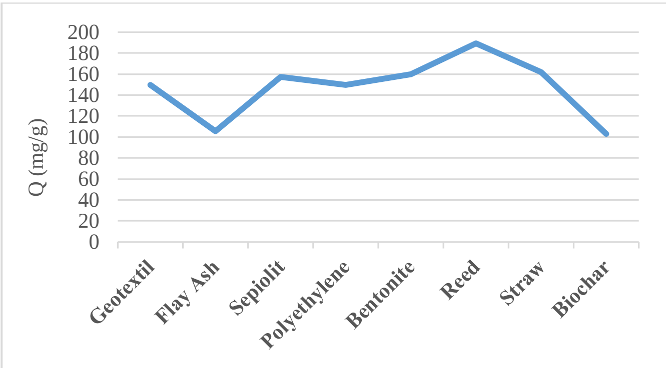

Figure 4. Yakakent Fisherman's Shelter Sea Water Adsorption Capacity.

Figures 2.5 and 2.6 show the degreasing effectiveness of sea water samples taken from Canik Fishermen's Shelters before and after water analysis filtration and after adsorption investigation, as well as the oil concentration after adsorption study.

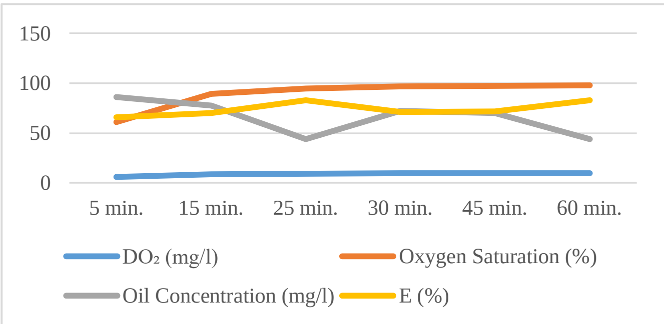

Figure 55. Canik Fisherman's Shelter Seawater Aeration DO_2, Oxygen Saturation and Oil Concentration and Percent Efficiency.

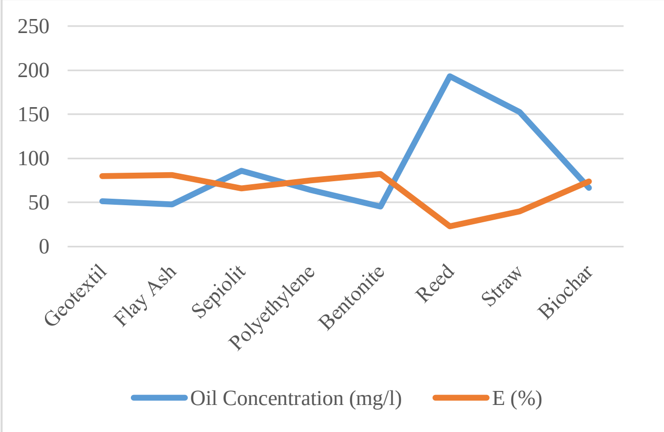

Figure 6. Canik Fisherman's Shelter Adsorption Oil Concentration and Oil Removal Efficiency.

3. RESULTS

A capacity study of the oil's adsorbing capacity was conducted using physical separation, filtration, aeration, and various adsorbent materials with samples taken from Yakakent and Canik Fishermen's Shelters. It was discovered that many adsorbent materials were effective in removing the pollution and pollution caused by the water containing oily/bloody aquaculture residues left on the sea surface after the transfer of the caught fish to the land and afterwards.

In the first research at Yakakent Fishing Shelter, the quality values of oily sea water and water after filtering were examined. The initial oil concentration was 270 mg/Land, and the oil concentration was 51.36 mg/L after filtration. According to the results, 81% of the grease is removed. For seawater samples collected at Yakakent Fishing Shelter, it can be seen that the pH value is appropriate after filtration, the redox value is decreasing, the dissolved oxygen concentration is high, the oxygen saturation is close to the lower limit value, the phosphorus value is appropriate, the conductivity value is rising, the ammonium concentration is within acceptable ranges, the chemical oxygen demand value is suitable, and the nitrogen limit value is below. In the second study, the water quality values of the sample were measured under stationary conditions and adsorption experiments were performed with perlite, festuca, Lolium, geotextile, zeolite, treatment sand adsorbents under these stationary conditions. Oil concentration was measured in adsorption experiments with perlite, festuca, Lolium, geotextile, zeolite, purification sand under stationary conditions. In the adsorption process, the removal efficiency by zeolite was found as 97%. While the pH value was 5.06, it was seen that the pH value increased between 7 and 8 with the adsorption of perlite and purification sand. An increase in pH was rarely observed with Festuca, Lolium, geotextile and zeolite adsorbents. The fact that the dissolved oxygen values have fallen too much and the result has also adversely affected the redox potential. In seawater samples taken from the fishermen's shelter, the dissolved oxygen value was initially found to be low and as a result of adsorption studies, it reached 2.4 mg/l as a result of the adsorption process with dissolved oxygen festuca. Oxygen saturation was seen to be low and it was obtained as 25.8% with the Festuca. It has been observed that the adsorption with zeolite and purification sand, where the conductivity value is low, increases compared to the initial value. As a result of adsorption trials with geotextiles in sea water samples, the phosphorus concentration was reduced from 20 mg/l to 4.4 mg/l and became compliant with the standards. The nitrogen concentration is well above the limit value at 117.34 mg/l. After the adsorption process with perlite, the nitrogen concentration was found to be close to the limit value of 0.4 mg/l. When Festuca, Lolium, geotextile, zeolite, purification sand was used as adsorbents, nitrogen concentrate and ammonium values were found to be below the limit. According to the results of COD analysis, it was found that the COD value in sea water was below the limit value in adsorption studies conducted with the use of perlite, Festuca, geotextile, treatment sand adsorbents. In the third study, after adding geotextile, fly ash, sepiolite, polyethylene, bentonite, sedge, sieve, biochar adsorbents to the sample and it has been determined that the oil removal efficiency is found as 99% with sedge and sieve.

The quality values of oily sea water and water after filtering were measured with the filtration method, which is the first research filtration of Canik Fishing Shelter. By measuring the dissolved oxygen demand, oxygen saturation, and oil at regular intervals, the oily sea water belonging to the Canik Fishing Shelter was aerated, and the percentage yield was calculated. Following filtration, oil concentration was determined to be 47.94 mg/l (down from 252 mg/l initially), and degreasing effectiveness was assessed to be 81%. The pH level both before and after filtering is within acceptable ranges. After filtration, it was seen that the redox value was reducing, the dissolved oxygen value was high, the oxygen saturation was close to the lower limit value, the phosphorus value increased but was below the upper limit value of 10 mg/l, the conductivity value increased, and the ammonium value did not reach the limit value. The chemical oxygen demand decreased from 82.78 mg/l to 4.32 mg/l after filtration and was below the limit value with the upper limit value of 25 mg/l, and the upper limit value of nitrogen was 0.5 mg/l. The second work was carried out aeration and oil concentration after aeration was measured as 44.25 mg/l and the oil removal efficiency was 83%. In the third study, when the oil removal efficiency was examined by adsorption using geotextile, fly ash, sepiolite, polyethylene, bentonite, sedge, sieve, biochar" adsorbents, the highest adsorption efficiency was found as 82% bentonite adsorbent.

CONCLUSION

Active fishing shelters were determined and sea water quality was monitored by taking sea samples in Samsun region. From the results, it has been determined that the sea in the fishermen's shelters is adversely affected by fish residues and oil. For these purposes, physical and chemical treatment and energy conversion alternatives were evaluated. With climate change, the changes in sea water quality and the increase in temperature will increase the problems of ecological life. In this study, adsorbent substances such as perlite, festuca, Lolium, zeolite, purification sand, geotextile, fly ash, sepiolite, polyethylene, bentonite, sedge, straw, bio charcoal were used. It is planned to apply adsorption from sea water with adsorbent inside the pads. Afterwards, it will be transferred to the facility in Samsun that converts waste into energy and a zero-waste management will be provided.

REFERENCES

[1]. Sciortino, J. A., "*Fishing Harbour Planning, Construction and Management (No.539).*" *Food and Agriculture Organization of the United Nations (FAO)*, 2010.

[2]. Ardali, Y., "Removal of Heavy Metals from Industrial Wastewater by Adsorption", Ondokuz Mayis University Graduate School of Sciences, Master Thesis, 1990.

[3]. Ozalp, H. B., "Oil Extraction from Fish Wastes and Biodiesel Production" Akdeniz University Institute of Science and Technology Master's Thesis, 2011.

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Determination of Surface Water Pollution Caused by Harmful Algae Growth: The Example of Irrigation Pond in Oltu District of Erzurum Province

Mevra Emec[1], Zeynep Eren[2]

Abstract

Surface water resources which are frequently exposed to Harmful Algae Blooms (HABs) due to the increasing pollution load in recent years due to the increase in temperature caused by climate change and the increase in surface run-off caused by extreme rainfall as a result of climate change are faced with the risk of the increasing concentrations of algal toxins into drinking water. Although HABs have caused the problem of eutrophication in surface waters especially at hot seasons in the past decades due to the water pollution, increasing surface water temperatures cause this problem to extended periods out of season and to be permanent for a long time. In recent years, there have been many studies focusing that the areas where HABs have expanded and their frequency has increased. For this reason, studies involving the detection and monitoring of algal toxins are gaining importance in order to control harmful algae growth at the water source, especially in drinking and utility water sources. Therefore, in this study, surface water sources were used to monitor in terms of two algal toxin compounds, Microcystin-LR (MC-LR) and Microcystin-RR (MC-RR), which are the main indicators of harmful algae growth in artificial ponds created for agriculture and livestock in Oltu District of Erzurum City.

Keywords: Harmful Algal Blooms, Eutrophication, Microcystins, Surface Water Pollution, Climate Change

1. INTRODUCTION

The increase in temperature caused by climate change and the increase in surface runoff due to excessive precipitation increase the nutrient input to water resources. Surface water resources are frequently faced with the threat of harmful algal blooms and the resulting algal toxins into drinking water. Although harmful algae growths have caused the problem of eutrophication (harmful algae blooms) in surface waters, especially in hot seasons, frequently due to water pollution in the past years, Increasing surface water temperatures with climate change cause this problem to spread to extended periods outside the season and to be permanent for a long time.

In recent years, there have been many studies showing that the areas where harmful algal blooms occur have expanded and their frequency has increased. For this reason, studies involving the detection and monitoring of algal toxins gain importance in order to control harmful algae growth at the source, especially in drinking and utility water sources. Among the cyanobacteria species, the most important species known to produce toxins is Microcystis. Such cyanobacteria cause taste and odor problems in drinking water resulting in the creation of hypoxic water bodies leading to the death of aquatic organisms, clogging of filters, pipes and other mechanical

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equipment in drinking water treatment plants. That cause the forming unaesthetic and unwanted smelling surface water scum. As revealed by the studies conducted with increasing frequency in recent years, it has a direct impact on human health beacuse of the production of toxins that is causing to the decrease in the use of water resources for recreation and tourism [1]

The harmful algal bloom problem is affected by various environmental factors such as nutrient concentration, light availability, temperature and salinity. Worldwide, especially in rural and underdeveloped areas, where people use untreated surface water as a source of drinking water increases the possibility of exposure to cell-bound and/or dissolved cyanotoxins, and acute and chronic effects occur depending on the amount of these toxins. In addition, harvesting and using the algae masses formed as a result of this cyanobacterial growth due to eutrophication in the aquatic environment in various parts of the world causes these permanent pollutants to mix with the groundwater through leakage and represents another source of drinking water contamination [2].

With increasing turbidity levels and high dissolved nutrient concentrations, water quality also declines. Additionally, cyanobacteria typically grow more efficiently at high temperatures compared to other phytoplankton species, suggesting they will have a competitive advantage in future warming conditions. Recent studies have shown that many toxin compounds are released into the aquatic environment with eutrophication and that these compounds can directly affect public health because they cannot be purified in drinking water treatment plants. These toxins are generally called cyanobacterial toxins and the most known and most researched compound, MC-LR, should not exceed 1 µg/L, the standard recommended by the World Health Organization (WHO) due to its carcinogenic properties. [3] The most important cyanobacterial poisoning event that people were exposed to outside the oral route occurred in 1996 in Brazil; Acute liver failure developed in 100 of 131 dialysis patients due to cyanobacterial contamination of water used for dialysis, and 52 of these patients died. [4] Among other episodes of human disease associated with cyanobacteria, a statistically significant correlation was found between drinking water from a reservoir containing Microcystis aeruginosa in Australia and signs of liver damage [5]. China has also a problem with a high incidence of primary liver cancer which is attributed to drinking water contaminated with cyanobacterial toxins [6]. Therefore, the protection of water resources becomes more and more important. To reduce the risk of toxic cyanobacterial growth in drinking water, a multibarrier approach is required, as shown in Figure 1 [7]. Accordingly, prevention of pollution of the water source and control at the source are considered as a priority, and it is important to use treatment technologies that will minimize the release of these toxins and to optimize these methods in source control operations. The last step is to monitor the toxin release. For this reason, determining and monitoring the amount of toxins in surface water resources is the most important step in eutrophication control.

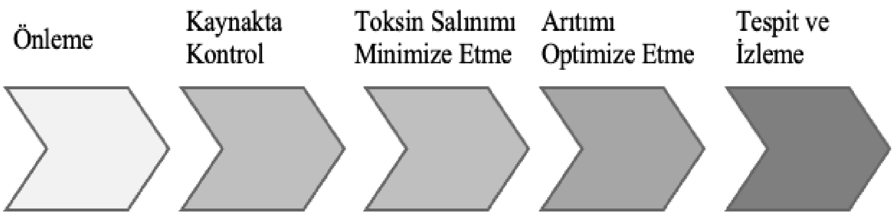

Figure.1 Multi-barrier approach developed for eutrophication control [7]

2. MATERIAL AND METHODS

For this reason, two main Microcystins, MC-LR and MC-RR, were detected and analyzed in the irrigation pond, Inanmis, in Oltu District in Erzurum City. Composite samples collected from the pond (Figure 2) in August 2022 were brought to the laboratory in dark-colored sample bottles in accordance with the sample storage conditions and were prepared for analysis within 48 hours by storing them at +4 ºC (Figure 3). Samples were taken once for the detection of microcystins. After detection of microcystins in ponds, sampling will continue at different temperature periods for seasonal monitoring studies. Therefore, the study only includes detection studies of microcystins.

Figure.2 Erzurum Province Oltu District Inanmis Pond2022.

Figure 3. Preparation of water samples taken from Inanmis Pond for LC-MSMS analysis

In this study, Oltu district Inanmis Pond was taken as an example. to detect harmful algae formations in the surface waters within the borders of Oltu District of Erzurum province. The ponds selected as the study area are mainly created for agricultural irrigation and animal husbandry. The most important cyanobacterial toxins from HABs, the main indicator Microcystin-LR (MC-LR) and Microcystin-RR (MC-RR), were detected in surface water samples from artificial ponds. Agriculture and animal husbandry in Erzurum Province Oltu District. MC-LR and MC-RR concentrations were analyzed by LC-MS/MS (Agilent Technology 6460 Triple Quad LC/MC) in Ataturk University Central Laboratories (DAYTAM - Eastern Anatolia High Technology Application and Research). Center).

3. RESULTS AND DISCUSSION

Composite samples taken from Inanmis Pond were made ready for LC-MS/MS analysis after filtering through a 0.22 µm cellulosic filter. After the sample was brought from the Inanmis pond, it was stored at +4 °C and analyzed immediately when it was ready for analysis. In the literature, storage conditions for microcystins are specified as a maximum of 48 hours at +4 ºC. The stable structure of microcystins and the fact that the samples are not subjected to any treatment are the main reasons that can prevent their deterioration until analysis.

The MC-LR and MC-RR concentrations of the sample analyzed in 3 replicates in the LC-MS/MS are found as shown in Table 1.

Table 1. MC-LR and MC-RR concentrations detected from the Inanmis pond

Pond	**pH**	**Sicaklik, ºC**	**MC-LR, µg/L**	**MC-RR, µg/L**
Inanmis	9.3	18.4	0.0701	0.1333

A study conducted in Lake Los Padres, Argentina in 2007, where MC-LR circles dissolved in water appeared at 0.04 ± 0.05 µg/L and MC-RR at 1.50 ± 2.15 µg/L [8]. An undissolved MC-RR was found to be 1.56 µg/L in the Yanghe Reservoir in China in 2010, while the MC-LR was determined as 0.544 µg/L [9]. Analyzes of 14 sites in Northern Ireland show that MC-LR covers the range of 0.004–0.014 µg/L and MC-RR covers the range 0.005–0.060 µg/L [10].

Considering the studies in the literature, it is seen that the MC-LR and MC-RR concentrations in artificial irrigation ponds reached the visible level in this study. Considering the 1 µg/L limit value determined by WHO for MC-LR, it is seen that the ponds observed in this study carry a low risk for humans and other living things. However, it is important to monitor microcystin concentrations in different seasons and for long periods in order to see the increase in concentrations. Therefore, the next step after detection studies is monitoring studies [11,12]. Regarding the monitoring of cyanotoxins, the two main goals of decision makers in drinking water supply systems are; first to detect the presence of cyanotoxin compounds and secondly to collect sufficient monitoring data to develop early warning models to reliably predict contamination.

4. CONCLUSIONS AND RECOMMENDATIONS

In this study, although cyanotoxins were not found in high concentrations in the analyzes made on the samples taken from the Inanmis pond of Erzurum Province Oltu District, MC-RR and MC-LR were detected in the water samples taken from the Inamis pond. Increasing harmful algal blooms around the world pose a significant threat to both the environment and public health. Therefore, it is necessary to develop sustainable and cost-effective treatment processes, as well as risk analysis and management tools.

Accurate measurement of cyanotoxin compounds and developing methods that can analyze them accurately will be the key step for eutrophication risk management, but due to the lack of legal regulations or almost non-existence in some countries, insufficient analytical capacity and scientific studies, regular monitoring for these compounds by the authorities. programs are rarely carried out. For this reason, it is essential to use support tools in decision-making, and studies on the detection of cyanotoxins, which are indicators of eutrophication, in water resources are important in terms of expanding, developing and guiding future studies in this field. Urgent measures are needed, especially in drinking water.

REFERENCES

[1]. S. M. Metev and V. P. Veiko, *Laser Assisted Microtechnology*, 2nd ed., R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.

[2]. Koker, L., Akcaalan, R., Dittmann, E., & Albay, M. (2021). Depth profiles of protein-bound microcystin in Kucukcekmece Lagoon. Toxicon, 198, 156-163.

[3]. WHO, (1998). "Cyanobacterial toxins: microcystin-LR", In: Guidelines for Drinking- Water Quality, second ed. Addendum to Volume 2, Health Criteria and Other Supporting Information. WHO, Geneva, Switzerland, pp. 95–110.

[4]. Jochimsen E M, Carmichael W W, An J S, Cardo D M, Cookson S T, Holmes C E, Antunes M B, de Melo Filho D A, Lyra T M, Bareto V S, Azevedo S M, Jarvis W R (1998). Liver failure and death after exposure to microcystins at a hemodialysis center in Brazil. N. Engl. J. Med. 338: 873–878

[5]. Metcalf, J.S., Codd, G.A. (2004). "Cyanobacterial Toxins in the Water Environment. A Review of Current Knowledge", Foundation for Water Research.

[6]. Harada, K. I., Tsuji, K., Watanabe, M. F., & Kondo, F. (1996). Stability of microcystins from cyanobacteria—III. Effect of pH and temperature. Phycologia, 35(sup6), 83-88.

[7]. He, X., Liu, Y. L., Conklin, A., Westrick, J., Weavers, L. K., Dionysiou, D. D., ... & Walker, H. W. (2016). Toxic cyanobacteria and drinking water: Impacts, detection, and treatment. Harmful algae, 54, 174-193.

[8]. Amé, M. V., Galanti, L. N., Menone, M. L., Gerpe, M. S., Moreno, V. J., & Wunderlin, D. A. (2010). Microcystin–LR,–RR,–YR and–LA in water samples and fishes from a shallow lake in Argentina. Harmful Algae, 9(1), 66-73.

[9]. Li, Z., Yu, J., Yang, M., Zhang, J., Burch, M. D., & Han, W. (2010). Cyanobacterial population and harmful metabolites dynamics during a bloom in Yanghe Reservoir, North China. Harmful algae, 9(5), 481-488.

[10]. Mooney, K.M., Hamilton, J.T.G., Floyd, S.D., Foy, R.H., Elliot, C.T., (2011). Initial studies on the occurrence of cyanobacteria and microcystins in Irish Lakes. Environ. Toxicol. 26, 566–570.

[11]. WHO, (2003). The World health report : 2003 : shaping the future. World Health Organization.

[12]. Minasyan, A., Christophoridis, C., Wilson, A. E., Zervou, S. K., Kaloudis, T., & Hiskia, A. (2018). Diversity of cyanobacteria and the presence of cyanotoxins in the epilimnion of Lake Yerevan (Armenia). Toxicon, 150, 28-38.

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Investigation Of The Effect Of Pore Sizes On Dm Formation Time, And Cleaning Frequency

Muge Pacal[1], Neslihan Semerci[2]

Abstract

Dynamic membrane (DM) technology was applied for treatment of synthetic dairy wastewater. The study consisted of two step. In first step of the study, changes in DM formation time and solid removal efficiency were investigated at different operational conditions using support materials having different pore sizes (20 and 40 µm) in an external filtration unit being situated at the outlet of up flow sludge blanket reactor. During the operation, three runs were done for each studied pore sizes and physical cleaning was done two times for each pore sizes. DM formation time became shorter as the pore sizes of support layer decreased for the initial stages of the support layer usage. On the other hand, after DM formation, support layer lost its original properties and its filtration characteristics became independent of pore size. Solid removal at different pore sizes was followed with turbidity measurements. The turbidity removal efficiency was more than 92 % for all pore sizes. The initial flux was 97 and 95 L/m^{2}h for 20 and 40 µm pore size, respectively. The flux after DM formation during operation with 20 µm pore size was slightly higher than 40 µm pore size. The cake layer resistance effect on total membrane resistance was evaluated for 40 µm pore size. It was calculated for run-3 as 2.34x 10^9 1/m corresponding 99.5 % of total resistance. According to these results, cake layer resistance composed most of the total resistance. Among the pore sizes tried, 20 µm was found to be optimum pore size considering DM formation time, flux, trans membrane pressure and treatment performance.

Keywords: Dynamic Membrane, Membrane Flux, Physical Cleaning, Membrane Resistance

1. INTRODUCTION

Huge amount of dairy products are consumed around the world. Its demand has been rising year by year in parallel with standard of living and population increase [1]. The main products are bottled pasteurized milk, yogurt, cheese, ice cream, cream, and butter [2]. A large amount of water is consumed by dairy industries to produce dairy products. The dairy wastewater includes lower toxic chemical substances than other industrial plant effluent [3]. Due to high COD contents, wastewaters of dairy industry are high in strength [4] and unstable in nature [5].

Conventional treatment methods have been applied to treat dairy industry effluents. However, many problems have been stated in the treatment of dairy wastewater by conventional methods. These are difficulties in removal of nitrogen and phosphorus, low sludge settleability and encountered problems in the removal of fat, oil, dyes, low resistance to shock loads, and high production of scum [6]. Up flow anaerobic sludge blanket (UASB) reactors have been used for treatment of dairy wastewater [5]. Dairy effluents include a very important amount of lipids. The accumulation of these lipids causes undesired sludge floatation problems that could result escape of biomass in UASB system [4,7].

The integration of a membrane into bioreactor, a membrane coupled reactor, can decrease solid losses from the reactor. DM could be favourable technique to solve the problems happened during treatment by Membrane Bioreactor (MBR) systems [8]. The formation of membrane fouling is an important disadvantage for

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conventional membrane during operation. The application of DM can turn this disadvantage into advantage. In the promising approach of DM filtration, membrane fouling is utilized for creating a low-cost, self-forming, and reformed membrane layer [8,9,10].

DM layers consist of an “underlying gel layer” and “cake layer”. An underlying gel layer forms through the attachment and deposition of the solutes and colloids on the support layer (fabric filter, nylon/dacron mesh) and strict tightly to the filter surface [8]. Thus, allowing the use of cheap support material instead of conventional membranes enables an important cost reduction in the treatment system. Using cheaper support materials instead of conventional membranes allow higher flux rates under lower transmembrane pressure [8]. The low cost support materials have large pore sizes that are mostly between 20 and 100 micrometer (μm). Thus, working with large pore size allows working with a higher flux at a very lower pressure [11].

According to Chu et al. [12], DM operation includes three stages. These are DM layer formation, filtration, and backwash. In DM formation stage, fine particles cannot be retained by support layer due to large pore size. Thus, this causes poor permeate quality in the effluent. Therefore, the effluent water needs to be recirculated into the system till high effluent quality is obtained. At filtration stage, the formation of DM is completed, and the effluent quality reaches to conventional membrane effluent quality. In last stage, backwash, which is one of the cleaning strategies, is applied due to decrease in flux as a result of fouling [11]. In addition to this, in DM studies, the flux, suspended solid (SS) and turbidity were used as an indicator of DM formation during operation [13]. The time when turbidity, suspended solid (SS) or flux becomes stable, indicates DM formation time [13].

There are three types of membrane module, which could be used for DM applications. These are flat-sheet, hollow fiber and tubular type [14]. When DM layer is formed, high-quality permeate in the effluent can be obtained. The high-quality effluent obtained by DM can be comparable with conventional membranes [11]. However, flux decreases due to membrane fouling. Thus, application of cleaning methods is needed to obtain longer and sustainable operation for effective DM layer control, accomplishing separation and reformation of DM. There have been reported studies about application of DM cleaning strategies [14]. The methods of physical cleaning are backwashing, biogas sparging, mixed liquor recycling, membrane relaxation, brushing; liquid cross-flow, vibration. Both sustainable and longer operation were achieved by using these cleaning methods due to govern DM fouling efficiently and accomplish separation of DM layer and regeneration of DM layer [14].

The support material, where DM forms, should have a convenient pore size for productive and sustainable DM operation. In this study, the influence of various pore sizes on DM formation, flux and filtration performance was investigated in order to detect the best convenient pore size of support layer for the system.

2. MATERIAL AND METHODOLOGY

2.1. Experimental Set-up

The experimental setup used in second part of the second phase is presented in Figure 1. The system was operated semi-continuously. The filtration operation was done about 9-10 hours in a day. A peristaltic pump (pump 1) (Watson Marlow 323) was employed to feed the synthetic milk wastewater into the UASB. Another peristaltic pump (pump 2) was used to collect the permeate from the reactor. The effluent of the bioreactor collected in a tank and used as filtration operation. The collected UASB effluent was fed into the cylindrical tube (1 L) using laboratory peristaltic pump (pump 3) (Labor Technik, Dusseldorf). As seen in Figure 1, the filtration was done in cylindrical tube, where the membrane module was located in. Mixing was carried out with a magnetic stirrer to keep solids in suspension. The aim was to enhance the contact between particulates and surface of nylon mesh. The filtrated water collected with a pump (pump 4) in a tank, where was set on a volumetric weighing scale. Experiments were carried out at room temperature (20°C).

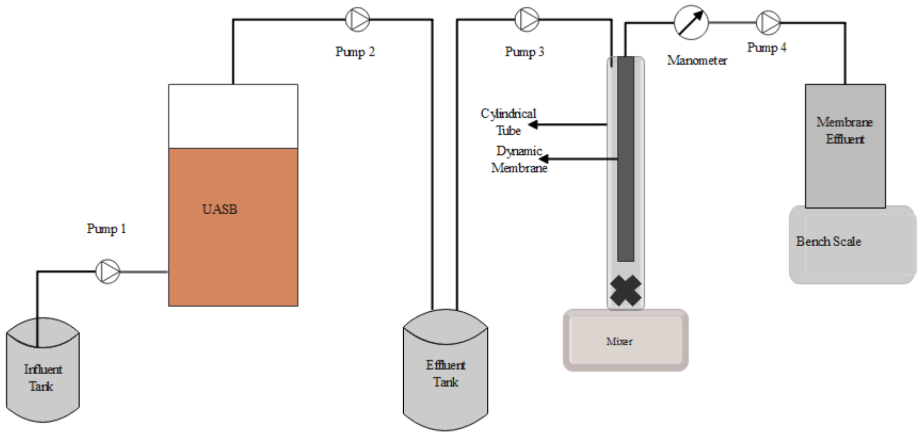

Figure 1. The diagram of experimental set-up

Characteristics of the support layers used in these experiments are presented in Table 1. Pressure was determined via 0~-1 bar Mini Dial Vacuum Pressure Gauge Manometer (Aterna, Turkey) placed in the effluent line. During whole operation, hydraulic retention time (HRT) was 33±6 hours and the temperature of the reactor was maintained at 28°C with an aquarium heater (EHEIM GmbH&Co.KG, Germany) in UASB. trans membrane pressure (TMP) was calculated according to the procedure reported by Le Clech et al. [15]. Filtration capability of membrane modules were evaluated with membrane resistance parameter. The membrane resistance, which is the sum of cake layer, gel layer and the intrinsic membrane resistance, was calculated according to Equation 1.

$$R_t = R_m + R_p + R_c \qquad (1)$$

Where R_m is the hydraulic resistance of virgin support layer, R_p is the irreversible filtration resistance due to the gel layer formation, and R_c is the reversible filtration resistance due to cake formation.

R_t was calculated by using flux and TMP obtained during dynamic membrane filtration. R_m was calculated by using the flux of tap water on virgin support layer and corresponding TMP. After the cake layer was removed from the support layer by spatula, the filtration of tap water on gel layer (including support layer) was done. As a result of filtration, the flux and TMP was used to calculate the resistance (R_m+R_p). R_p was calculated by subtracting R_m from R_m+R_p. R_c was calculated by subtracting R_t from the sum of R_m and R_p.

Table 1. Characteristics of the submerged membrane module

Category	**Module**
Membrane Module Type	Tubular
Pore size, µm	20-40
Material	Polyester
Effective Filter Area, m^2	0.014

2.2. Experimental Plan

The effect of support material pore size on the filtration behaviors was assessed during start-up and stabilized stages of DM. The various range of support materials (20 and 40 µm) were used in filtration operation. During the operation, when TMP increased almost higher than 800 mbar, filtration continued for a while. The membrane module was taken away in that case and cleaned with tap mater to remove cake layer on nylon mesh. After physical cleaning, membrane module was put into cylindrical tube. The filtration was repeated three times and physical cleaning was carried out at the end of each filtration period. In other words, in totals, three runs were carried out for each pore sizes. Initial fluxes together with test time are presented in Table 2 for all studied pore sizes and number of run phase.

Table 2. Applied mesh pore sizes and operating conditions in all tested runs

Runs	Mesh Pore Size, µm	Initial Flux, L/m^{2}h	Test Time, Hours
Run-1	20	97	9.26
Run-2	20	73	11.66
Run-3	20	91	10.083
Run-1	40	95	68.43
Run-2	40	89	64.03
Run-3	40	55	14.8

2.3. Wastewater Characteristics and Seed Sludge

During filtration operation, the characteristics of UASB effluent is presented in Table 3.

Table 3. The characteristics of UASB effluent used in filtration experiment

Parameters	Value
COD, mg/L	1817±728
SS, mg/L	1477±660.8
Turbidity, NTU	818±246
pH	7.73

3. RESULTS AND DISCUSSION

3.1. Filtration and Treatment Performance of DM

The applied initial flux was 97 L/m^{2}h in run-1 for 20 µm pore size (Figure 2a). The important increase in TMP happened after 2 hours of operation. DM formation took 5.31 hours during operation with 20 µm pore size (Table 4) and this was shorter than during operation with 40 µm pore size. This could be due to less solid retainment on support material with large pore size (40 µm) in the beginning of operation. Li et al.[13] reported that DM with a large pore size had longer formation time and they added that small particles were less likely to be attached to mesh with large pore size during DM formation until detention of large particles. After DM formation happened in 20 µm pore size of support layer, the flux continued in range of 45 and 29 L/m^{2}h with continuous increase in cake layer thickness.

The initial turbidity in permeate was 129 NTU in run-1 during operation with 20 µm pore size (Figure 2b). Turbidity almost became stable with DM formation. The average turbidity in permeate was 23.05±4.4 NTU from 5.31 hours to the end of operation (Table 4). In the end of run-1, DM was taken from the system and physical cleaning was done. Then the membrane module was integrated to the system for run-2. The same steps were applied for run-3.The initial flux was 73 L/m^{2}h in run-2 that it was lower than initial flux value in run-1 whereas it was 91 L/m^{2}h in run-3. The higher initial flux was observed in run-3 than run-2. The presence of temporary irreversible fouling resulted lower initial flux, taking place at the beginning of run-2 so the initial flux in run-3 recovered better than run-2. DM formation completed faster in the following runs (run-2 and run-3) and this showed the effect of irreversible fouling on DM formation. As for TMP, it increased to 768 mbar in 2.4 hours and continued with this value till the end of operation in run-1. On the other hand, TMP increased to the same value in a shorter time (35 minutes) in run-2 and it reached to 919 mbar in 10.43 hours of operation (Figure 2a).

Table 4. Applied mesh pore sizes and operating conditions in all tested runs

Pore Size	20, µm	40, µm
DM Formation Time (Run-1), hour	5.31	41.16
Average TMP After DM Formation (Run-1), mbar	768±0.8	1003±9.1
Average TMP After DM Formation (Run-2), mbar	868±51	997±1.9
Average TMP After DM Formation (Run-3), mbar	974±22	818
Flux After DM Formation (Run-1), L/m^2h	45-29	37-24
Flux After DM Formation (Run-2), L/m^2h	16-9	12-11
Flux After DM Formation (Run-3), L/m^2h	25-6	8-7

In run-3, TMP raised to 969 mbar in 61 minutes, continued with the value of approximately 974 mbar till the end of operation. It could be inferred that after physical cleaning, TMP improved quickly. Moreover, the spikes in turbidity were not observed in run-2 and run-3. As seen in Figure 2b, more solid retainment was observed in run-3 compared to run-2 such that the maximum turbidity in permeate was 252 and 139 NTU in run-2 and run-3, respectively. As mentioned just before, the irreversible fouling on previous runs (run-1, run-2) caused more solid retainment in the following runs (run-2 and run-3). After DM was formed, the average turbidity in filtered effluent was 41±5 NTU in run-2, and 39±6 NTU in run-3.

The initial flux was 95 L/m^2h during operation with 40 µm pore size in run-1 (Figure 2d). During operation of 40 µm pore size in run-1, after DM formation completed, maximum value of TMP was 1018 mbar which was higher than recorded TMP value during operation with 20 µm pore size. This result could be due to longer operation time of 40 µm pore size that resulted more solid retainment, so higher TMP. The flux continued to decrease gradually with development of DM formation and ended with a value of 24 L/m^2h. As showed in Table 4, after DM formation, the flux values of higher pore size (40 µm) exhibited lower flux values than smaller pore size (20 µm) due to its having higher TMP.

Prior to DM formation, the spikes in turbidity were observed during operation with 40 µm pore size in run-1 (Figure 2e) and it reached to 1000 NTU in 9.28 hours of operation. As mentioned before, larger pore size nylon mesh had low capability of solid retainment. Moreover, it could be inferred that size of the most of the particles was lower than 40 µm. The feed, coming from UASB effluent, was used for filtration and the average particle size in UASB was 35 µm [16]. Thus, the important quantity of particles had size less than pores of support layer (40 µm). As mentioned before, small particles that had lower size than pore size of support layer likely less attached inside pore of the support layer. Small particles passed through the pores of support layer that these were observed as spikes in permeate turbidity (Figure 2e). As seen in Figure 2(e), the variation in turbidity continued for a while. This showed that effective solid removal needed longer time for large pore sizes.

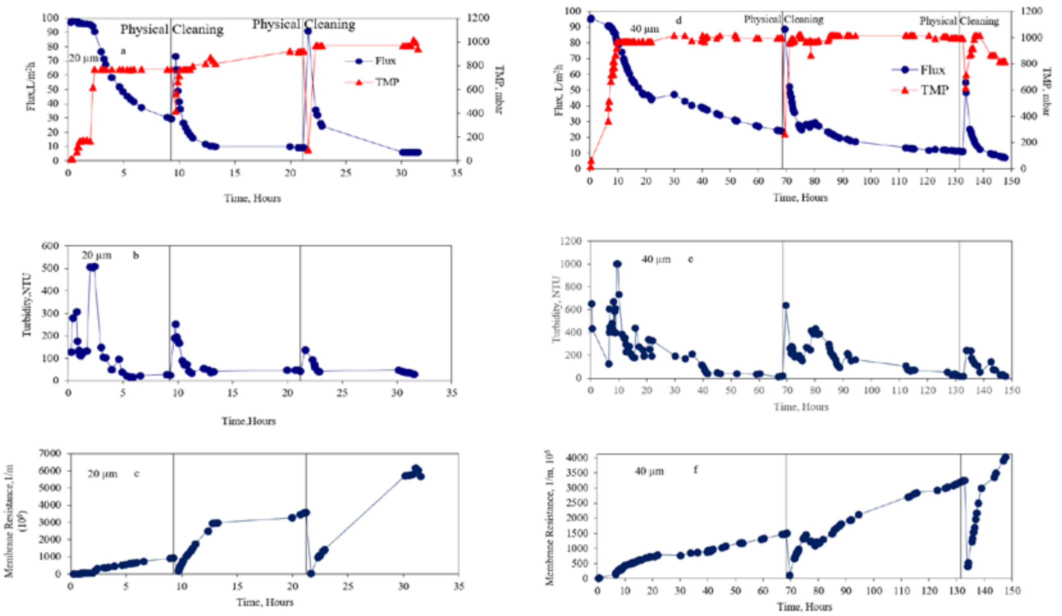

Figure 2. Change of (a) Flux and TMP, (b) Turbidity and (c) Membrane Resistance versus time at support material with 20 µm and Change of (d) Flux and TMP, (e)Turbidity and (f) Membrane Resistance versus time at support material with 40 µm

Turbidity became stable with DM formation after 41.16 hours of filtration operation. Afterwards, the turbidity in permeate was 30±8 NTU in run-1. This value was higher than the values obtained during operation with 10, 20 µm pore size in run-1. It seems that support layer with smallest pore size resulted more solid retainment and lowest turbidity in permeate. Thus, the pore size effect on solid retainment was clearly observed in first run. However, the similar results were not observed in terms of turbidity in the following runs (run-2 and run-3) due to the fact that irreversible fouling changed the original pore size. Additionally, other factors such as the feed characteristics and operation time could affect solid retainment capability of membrane in the following runs (run-2 and run-3).

The initial flux was 89 L/m^{2}h in run-2 and 55 L/m^{2}h in run-3 (Figure 2d). In the following runs, the similiar variations in flux, TMP and turbidity were observed as in 20 µm pore size due to irreversible fouling, changing the original pore size of support layer. After DM formation, the flux was continued with range of 12 and 11 L/m^{2}h in run-2 and with range of 8 and 7 L/m^{2}h in run-3 (Figure 2d). As seen in Figure 2(e), in comparision with run-1, the less fluctuations in turbidity in membrane effluent were observed in run-2 and run-3. As mentioned above, the irreversible fouling, happened in run-1, improved solid retainment in the following runs, thus less variation in turbidity were observed in the following runs. Moreover, it was seen that support layer lost its original properties as a result of DM formation and its filtration charactristics became independent of pore size in the following runs.

The turbidity removal efficiency was similar (more than 92 %) and high for all pore sizes nylon meshes. All these results showed that 20 µm pore size seemed to be optimum considering DM formation time and treatment performance.

3.2. DM Resistance

The membrane resistance is used to determine the filtration capacity of membranes [17]. It was calculated for all pore sizes applied in these experiments. The average membrane resistance of all pore sizes for each run is presented in Table 5. Membrane resistance for 20 µm pore size, is showed in Figure 2(c). Membrane resistance was approximately $2x10^8$ 1/m in the early stage of DM. After DM was formed, the membrane resistance increased to 6.08 $x10^8$ 1/m in run-1. The operation ended with a value of $9.37x10^8$ 1/m. This value was lower than the values reported in other studies [18, 19]. The important reason increase in membrane resistance on next runs (run-2 and run-3) was irreversible fouling. This fouling layer caused more solid retainment in the following runs (run-2, run-3). The similar results about increase in membrane resistance in the following runs were observed for 40 µm pore size because of irreversible fouling (Figure 2f).

Table 5. The membrane resistance, calculated during the operation with 20 and 40 µm pore size

	Average Membrane Resistance,1/m	
Pore size	20 µm	40 µm
Run-1	$3.2x10^8$ ±$6x10^7$	$6.78x10^8$±$5x10^7$
Run-2	$1.9x10^9$ ±$3x10^8$	$1.87x10^9$±$1.2x10^8$
Run-3	$4x10^9$ ±$7.1x10^8$	$2.36x10^9$±$3.23x10^8$

Contrary to expected, the membrane resistance during operation with 40 µm pore size was higher than 20 µm pore size in run-1 (Table 5). As mentioned before, TMP during operation 40 µm pore size was higher than 20 µm pore size. This could be due to occurrence of more solid deposition on nylon mesh and this improved TMP. The operation time in 40 µm pore size was longer than 20 µm pore size. Thus, long system operation results more solid retainment on support layer that improves membrane resistance. The filtration resistance of DM was remarkably much lower than that of MF/UF membranes in the range of 10^{12}–10^{14} 1/m during long-term sustainable operation [20]. In addition to this, low filtration resistance in DM operation implies superior filtration capacity of DM over conventional membranes, and also reduction in energy consumption of the system [18]. The cake layer resistance effect on total membrane resistance was evaluated for 40 µm pore size (Table 6). Pore blocking resistance was calculated as 1.36 x 10^7 1/m and instinct membrane resistance was calculated as $7.13x10^6$ 1/m. The cake layer resistance was calculated as 2.34x 10^9 for run-3 and it was 99.5 % of total resistance. According to the results, cake layer resistance composed most of the total resistance. This result was consistent with [21] reporting that cake resistance was responsible for over 98% of the total fouling. As mentioned by Chang and Kim [22], the cake layer formation was a major factor responsible for the overall flux decline.

Table 6. The membrane resistance of 40 µm pore size; Total resistance, pore blocking, cake resistance and virgin layer

Membrane Resistance,1/m	Run-3
Total Resistance	$2.36x10^9$
Cake Resistance (Reversible Fouling)	$2.34x10^9$
Pore blocking (Irreversible Fouling)	6.47 $x10^6$
Virgin Layer	7.13x 10^6

CONCLUSION

The effect of pore size on DM formation and operation was investigated. The obtained results showed that as pore sizes of support layer being taken into operation for the first time, decreased, DM formation time became shorter and filtration efficiency got higher. Additionally, after DM formation, support layer lost its original properties, and its filtration characteristics became independent of pore size. Moreover, during operation with large pore sizes, cleaning frequency was decreased. Longer continuous operation was provided despite lower effluent quality in the beginning of experiment. Among the sizes tried, 20 µm was found to be optimum pore size considering DM formation time, flux, TMP and treatment performance.

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REFERENCES

[1]. D. Karadag, O.E. Koroglu, B. Ozkaya, M. Cakmakci, S. Heaven, C. Banks, and A. Sema-Maza, "Anaerobic granular reactors for the treatment of dairy wastewater: A review", *Int Dairy J.*, vol.68, pp.459-470, Feb.2015.

[2]. T.J. Britz, C. Van Schalkwyk and Y. Hung. (2006) Treatment of dairy processing wastewaters [Online]. Available: https://edisciplinas.usp.br

[3]. G.J. Joshiba, P.S. Kumar, C.C. Femina, E. Jayashree, R. Racchara, S. Sivanesan, "Critical review on biological treatment strategies of dairy wastewater", *Desalination Water Treat.*, vol.160, pp.94-109, Aug.2019.

[4]. D. Karadag, O.E. Koroglu, B. Ozkaya, M. Cakmakci, "A review on anaerobic biofilm reactors for the treatment of dairy industry wastewater", *Process Biochem.*, vol.50, pp.262-271, Feb. 2015.

[5]. B. Demirel, O. Yenigun and T.T. Onay, "Anaerobic treatment of dairy wastewaters: A review", *Process Biochem.*, vol.40, pp.2583-2595, Jul. 2005.

[6]. L.H. Andrade, G.E. Motta and M.C.S. Amaral, "Treatment of dairy wastewater with a membrane bioreactor," *Braz J Chem Eng.*, vol.30, pp. 759 – 770, Oct.-Dec. 2013.

[7]. K. Karthiyen and J. Kandasamy, Water and wastewater treatment technologies-Up flow anaerobic sludge blanket (UASB) reactor in wastewater treatment, S.Vigneswanan Ed. Oxford, United Kingdom: Eolss Publishers, 2009.

[8]. M. E. Ersahin, H. Ozgun, R.K. Dereli, I. Ozturk, K. Roest and J B. van Lier, "A review on dynamic membrane filtration: materials, applications and future perspectives," *Bioresour Technol.*, vol.122, pp:196-206, Oct. 2012.

[9]. L. Alibardi, R. Cossu, M. Saleem, A. Spagni, "Development and permeability of a DM for anaerobic wastewater treatment," *Bioresour Technol.*, vol.161, pp:236-244, Jun. 2014.

[10]. Y. Zhang, Y. Zhao, H. Chu, B. Dong, X. Zhou, "Characteristics of dynamic membrane filtration: structure, operation mechanisms, and cost analysis," *Chin Sci Bull*, vol. 59, pp: 247–260, Dec. 2014.

[11]. S.M. Mahat, R. Omar, A. Idris, S. Kamal, A. Idris, "Dynamic membrane applications in anaerobic and aerobic digestion for industrial wastewater: A mini review," *Food Bioprod Process.*, vol.112, pp.150-168, Nov. 2018.

[12]. H. Q. Chu, D.W. Cao, W. Jin, B. Z. Dong, "Characteristics of bio-diatomite dynamic membrane process for municipal wastewater treatment," *J Membr Sci.*, vol:325, pp. 271-276, Nov. 2008.

[13]. L. Li, G. Xu, H. Yu, "Dynamic membrane filtration: Formation, filtration, cleaning and applications," *Chem Eng Technol.*, vol:41, pp. 7-18, Jun. 2017.

[14]. Y. Hu, C.X. Wang, H.H. Ngo, Q. Sun, Y. Yang, "Anaerobic DM bioreactor (AnDMBR) for wastewater treatment: A review," *Bioresour Technol.*, vol:247, pp.1107–1118, Sep. 2018.

[15]. P. Le Clech, B. Jefferson, I. S. Chang, S. J. Judd, "Critical flux determination by the flux-step method in a submerged membrane bioreactor," *J Membr Sci.*, vol:227, pp.81-93, Dec. 2003.

[16]. M. Pacal, N. Semerci, B. Calli, "Treatment of synthetic wastewater and cheese whey by the anaerobic dynamic membrane bioreactor," *ESPR.*, vol: 26, pp. 32942–32956, Sep. 2019.

[17]. J. Xiong, D. Fu, R.P. Singh, J. J. Ducoste, "Structural characteristics and development of the cake layer in a dynamic memrbane bioreactor," *Sep Sci Technol.*, vol:167, pp.88-96, Jul. 2016.

[18]. F. Sun, N. Zhang, F. Li, X. Wang, J. Zhang, L. Song, S. Liang,"Dynamic analysis of self-forming DM (SFDM) filtration in submerged anaerobic bioreactor: Performance, characteristic, and mechanism," *Bioresour Technol.*, vol: 270, pp. 383–390, Sep. 2018.

[19]. X. Zhang, Z. Wang, Z. Wu, F. Lu, J. Tong, L. Zong, "Formation of dynamic membrane in an anaerobic membrane bioreactor for municipal wastewater treatment," *Chem Eng J.*, vol:165, pp.175-183, Nov. 2010.

[20]. H.J. Lin, K. Xie, B. Mahendran, D. M. Bagley, K. T. Leung, S. N. Liss, B.Q. Liao, " Sludge proporties and their effects on Blocking in submerged anaerobic membrane bioreactors (SAnMBRs)," *Water Resour.*, vol:43, pp. 3827-3837, Jun. 2009.

[21]. Y. Liu, H. Lui, Haining, L. Cui, K. Zhang, "The ratio of food-to-microorganism (F/M) on membrane fouling of anaerobic membrane bioreactors treating low-strength wastewater," *Desalin.*, vol:297, pp. 97-103, Jul. 2012.

[22]. I. Chang, S. Kim, "Wastewater treatment using membrane filtration-effect of biosolids concentration on cake resistance," *Process Biochem.*, vol:40, pp.1307-1314, Mar. 2005.

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Efficiency of Activated Carbon Obtained from Rosehip Marmalade Waste in Reactive Blue 28 Dye Adsorption

Sahra Dandil[1]

Abstract

Activated carbon is widely used as an effective adsorbent in the removal of many different pollutants in adsorption processes due to its large surface area and high porosity. Especially in water treatments, dyes, which are one of the most common pollutants that mix with the aqueous environment as a result of various industrial activities, is encountered. In this study, the production of activated carbon as a cheap and effective adsorbent from rosehip marmalade waste, which is a natural waste, and the removal of dye from aqueous solutions with this activated carbon were investigated. Zinc chloride ($ZnCl_2$) was used as the activation agent in the production of activated carbon. $ZnCl_2$: rosehip marmalade waste was mixed in a mass ratio of 2:1 and kept at 90 °C for 2 hours. Then, the dried sample was treated in a nitrogen atmosphere at 600 °C at a heating rate of 5 °C/min at a flow rate of 100 mL/min for 1 hour. The sample washed with distilled water was dried and activated carbon was prepared. The prepared activated carbon was used as an adsorbent in the adsorption of Reactive Blue 28 dye. Adsorption studies were carried out at a pH range of 1-11, 50 ppm dye solution concentration, and 1 g/L adsorbent dosage. Depending on the pH, the concentration changes in the dye solutions over time were followed and the highest removal was obtained at pH 1 as 72.71% at 44 hours. Kinetic studies of the adsorption process were carried out. Pseudo-first order, pseudo-second order and intraparticle diffusion kinetic models were examined to evaluate the process in terms of kinetics. Regression coefficients (R^2) for pseudo-first-order, pseudo-second-order and intra-particle diffusion models were obtained as 0.9967, 0.9713 and 0.9906, respectively. Accordingly, it was determined that the process fits the pseudo-first-order kinetic model and the intra-particle diffusion model.

Keywords: Activated carbon, Adsorption, Reactive Blue 28, Rosehip, Waste

1. INTRODUCTION

Harmful materials that arise as a result of activities such as domestic, agricultural or industrial can mix with the water as pollutants, cause water pollution and reduce the quality of the water [1]. Pathogens, heavy metals, suspended solids, nutrients, dyes, and agricultural pollutants are among these harmful pollutants [2], [3]. Water treatment refers to making the water that has become unusable due to various pollutants usable by physical, chemical and biological methods [4]. One of the methods used in the removal of water-soluble impurities is adsorption [5]. In water treatment, adsorption takes place as pollutants dissolved in water (adsorbate) adhere to a porous structure (adsorbent). The most commonly used adsorbents in adsorption processes are activated carbons. Activated carbon is used in adsorption processes with its high surface area, porosity and efficiency and low cost [6]. Activated carbons can be prepared from natural or synthetic precursors [7]. Production of activated carbon from natural materials, especially from natural wastes, is highly preferred due to its low cost and contribution to waste disposal. Pomelo peel [8], pepper stem [9], groundnut shell [10], pineapple peel [11] and bamboo [12] can be given as examples of activated carbons synthesized from natural materials and used in adsorption processes in studies published in recent years. It is known that 10,000 tons of dye is discharged into 100 tons of water in the textile industry for dyes that are used extensively in the textile industry as well as in the paper, rubber, plastic, cosmetics, printing and leather industries. This situation prevents access to clean and

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healthy water and causes environmental and health problems worldwide. In addition to the complex structure and stability of dyes, their removal from water has become necessary due to the damage they cause [13].

This study aims to achieve efficient dye adsorption with low-cost material. Accordingly, activated carbon obtained from rosehip marmalade waste was used as an adsorbent in the adsorption of Reactive Blue 28 dye. Zinc chloride ($ZnCl_2$) was used as a chemical activation agent. The behavior of the process over time was followed for different pH values. Also, kinetic studies were examined with the three most commonly used kinetic models, the pseudo-first-order kinetic model, the pseudo-second-order kinetic model and the intra-particle diffusion model.

2. MATERIALS AND METHODS

2.1. Materials

Rosehip marmalade waste was collected, dried and ground. Then, grains in the 0.090-0.250 mm size range were selected by sieving and used for experiments. Reactive Blue 28 dye was supplied from a textile dye factory in Turkiye. $ZnCl_2$ was used as an activation agent and purchased from Panreac.

2.2. Synthesis of the Activated Carbon

$ZnCl_2$: rosehip marmalade waste was mixed in a mass ratio of 2:1. The mixture was kept at 90 °C for 2 hours. Then, it dried in an oven. The sample was treated in a nitrogen atmosphere at 600 °C at a heating rate of 5 °C/min at a flow rate of 100 mL/min for 1 hour. Then, the sample was washed with distilled water several times and dried.

2.3. Adsorption Experiments

The activated carbon was used in the adsorption of Reactive Blue 28 dye. Experimental studies were carried out with 50 mL dye solutions in a shaker (Thermal H11960) at a constant shaking speed of 200 rpm and room temperature. The experiments were followed for 44 h at a pH range of 1-11, 50 ppm dye solution concentration, and 1 g/L adsorbent dosage.

To determine the dye concentrations in aqueous solutions, absorbance values were obtained by a UV-VIS spectrophotometer (Perkin Elmer, Elmer Analyst 800) at 585 nm which Reactive Blue 28 dye had maximum absorbance.

2.4. Equations

Adsorption capacity and removal efficiency values were calculated to determine the performance of the adsorption process. Also, the kinetic evaluation of the processes was carried out. The pseudo-first-order kinetic model, the pseudo-second-order kinetic model and the intra-particle diffusion model were used for kinetic studies. The used adsorption capacity, removal efficiency and kinetic model equations are given in Table 1.

Table 1. Equations

	Equations
Adsorption capacity	$q_e = \frac{(C_0 - C_e)xV}{m}$
Removal efficiency	$\text{removal } \% = \frac{(C_0 - C_e)x100}{C_0}$
Pseudo-first-order	$log(q_e - q_t) = \log q_e - \frac{k_1}{2.303}t$
Pseudo-second-order	$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e}$
Intra-particle diffusion	$q_t = k_{int} t^{0,5} + C$

where; qe: adsorption capacity (mg/g), Co: initial dye concentration (mg/L), Ce: dye concentration at equilibrium (mg/L), V: volume (L), m: adsorbent mass (g), t: time (min), qt: the amount of adsorbate adsorbed on the adsorbent at time t (mg g^{-1}), k_1: pseudo-first-order rate constant (min^{-1}), k_2: pseudo-second-order rate constant (g mg^{-1} min^{-1}), k_{int}: intra-particle diffusion rate constant (mg/g.$min^{0,5}$), and C: constant [14].

3. RESULTS AND DISCUSSION

The effects of pH and time parameters were studied for the adsorption of Reactive Blue 28 dye by activated carbon synthesized from rosehip marmalade waste as an adsorbent. Accordingly, solutions of the dye were prepared in the pH range of 1-11, and absorbance values were determined by taking samples at certain times for 44 hours for each solution. To convert the absorbance values of the samples to concentration, the dye solutions at different concentrations were prepared and the calibration graph indicated in Figure 1 was prepared.

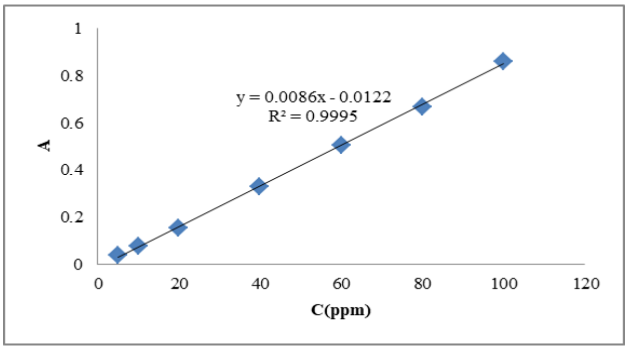


Figure 1. Calibration graph of Reactive Blue 28 dye

The pH and contact time parameters for the processes were followed simultaneously. Figure 2 shows the graph of removal efficiency over time for each pH value. According to Figure 2, although irregularities were observed in the early times of adsorption, adsorption behaviors were regulated with time. As given in Figure 2, the highest removal was obtained at pH 1. In addition to Figure 2, Figure 3 shows the removal efficiency values obtained for each pH value. According to Figure 3, after 44 hours, removal efficiencies were determined as 72.71, 50.08, 61.94, 54.84, 35.18 and 0 % for pH 1, pH 3, pH 5, pH 7, pH 9, and pH 11, respectively.

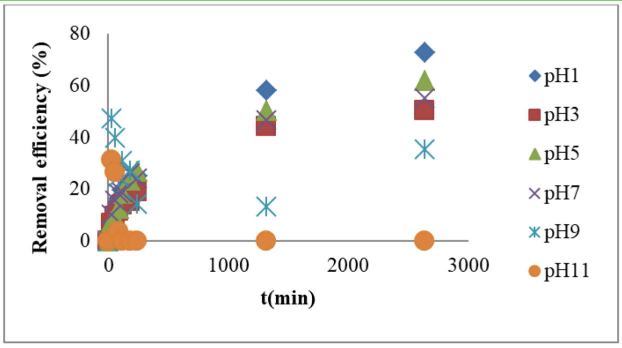


Figure 2. Removal efficiency (%)-t (min) graph

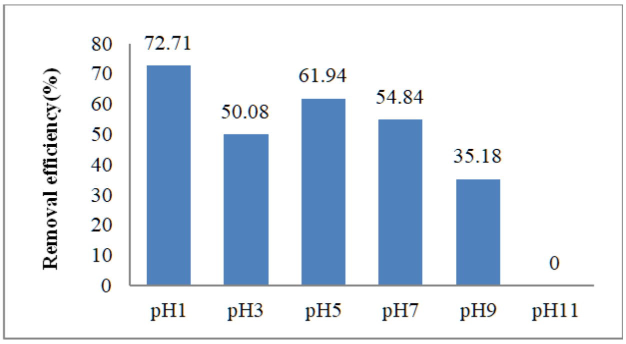
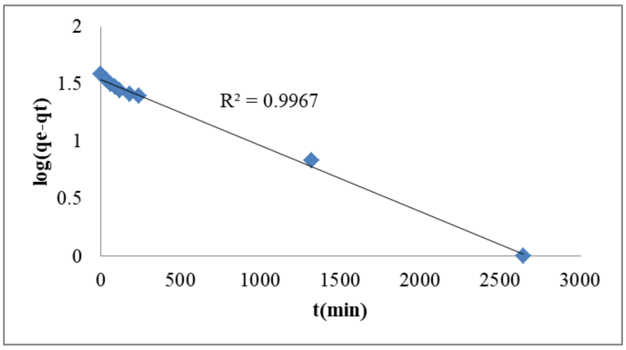
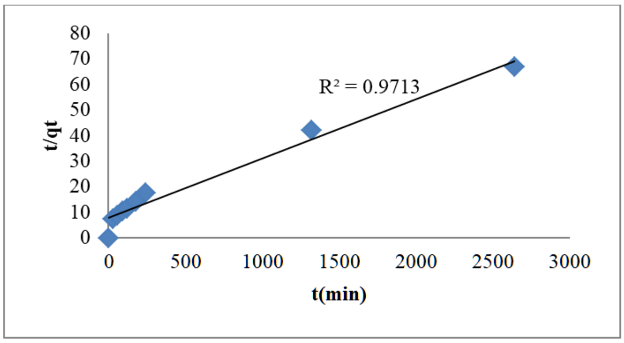


Figure 3. Removal efficiency (%)-pH graph

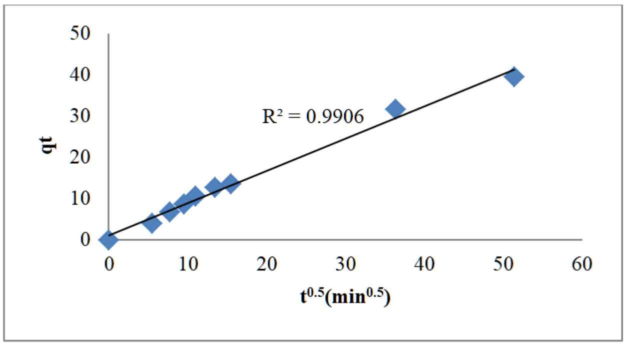
Adsorption kinetics provides information about rate-limiting steps, mechanisms and the best conditions of adsorption processes [15]. The pseudo-first-order kinetic model, the pseudo-second-order kinetic model and the intra-particle diffusion model were used for kinetic studies of the Reactive Blue 28 dye adsorption process and graphs of the models were given in Figure 4. According to the correlation coefficiencies (R^2) of the graphs seen in Figure 4, the highest R^2 values were obtained for pseudo-first-order kinetic model and intra-particle diffusion model as 0.9967 and 0.9906, respectively. Therefore, the process was found to be compatible with the pseudo-first-order kinetic model and the intra-particle diffusion model. The pseudo-first-order kinetic model clarifies the adsorption processes with the adsorption capacity of the adsorbent [16]. This surface reaction model describes that one adsorbed ion is in adherence to one unoccupied active site of the adsorbent surface [16], [17]. For the intra-particle diffusion model, the straight line passes through the origin indicates that intra-particle diffusion is solely the rate-limiting process [18]. The kinetic parameters of the adsorption kinetic models were also calculated and presented in Table 2.



(a)



(b)



(c)

Figure 4. (a) pseudo-first-order kinetic model, (b) pseudo-second-order kinetic model, (c) intra-particle diffusion model graphs

Table 2. Kinetic parameters of the kinetic models

Pseudo-first-order kinetic model			Pseudo-second-order kinetic model			Intra-particle diffusion model		
k_1 (x10^3) (min^{-1})	$q_{e,cal}$ (mg g^{-1})	R^2	k_2 (x10^5) (g mg^{-1} min^{-1})	$q_{e,cal}$ (mg g^{-1})	R^2	k_{int} (mg $g^{-1}min^{-0.5}$)	C (mg g^{-1})	R^2
1.38	34.63	0.9967	7.01	42.92	0.9713	0.78	1.07	0.9906

4. CONCLUSIONS

In the study, the production of activated carbon as a cheap and effective adsorbent from rosehip marmalade waste, which is a natural waste, and the adsorption of dye by the activated carbon were investigated. The activated carbon was used in the adsorption of Reactive Blue 28 dye. Adsorption studies were carried out at a pH range of 1-11, 50 ppm dye solution concentration, and 1 g/L adsorbent dosage. Depending on the pH, the concentration changes in the dye solutions over time were followed and the highest removal efficiency was determined as 72.71% at pH 1 and 44 hours. Pseudo-first order, pseudo-second order and intra-particle diffusion kinetic models were examined to evaluate the process in terms of kinetics. R^2 values for pseudo-first-order, pseudo-second-order and intra-particle diffusion models were obtained as 0.9967, 0.9713 and 0.9906, respectively. Accordingly, it was determined that the process fits the pseudo-first-order kinetic model and the intra-particle diffusion model. The pseudo-first-order kinetic model describes that one adsorbed ion is in adherence to one unoccupied active site of the adsorbent surface. The intra-particle diffusion model explains that the intra-particle diffusion is solely rate-limiting process.

REFERENCES

[1]. R. F. Ajayi, S. Barry, M. Nkuna, N. Ndou, T. Rakgotho, S. Nqunqa, N. Ngema, V. Thipe and T. Muluadzi, *Emerging Freshwater Pollutants,* T. Dalu and N.T. Tavengwa, Ed. Amsterdam, Netherlands: Elsevier, 2022.

[2]. J. M. Gooty, M. Srinivasulu, J. A. N. Mosquera and S. N. S. Llaguno, *Environmental Micropollutants,* M. Z. Hashmi, S. Wang and Z. Ahmed, Ed. Amsterdam, Netherlands: Elsevier, 2022.

[3]. K. L. Wasewar, S. Singh and S. K. Kansal, *Inorganic Pollutants in Water*, P. Devi, P. Singh and S. K. Kansal, Ed. Amsterdam, Netherlands: Elsevier, 2020.

[4]. A. J. Englande Jr, P. Krenkel and J. Shamas, "Wastewater treatment &water reclamation", *Reference module in earth systems and environmental sciences*, 2015.

[5]. S. B. Pillai, *Handbook of Water and Used Water Purification*, J. Lahnsteiner, Ed. Berlin, Germany: Springer, 2020.

[6]. O. S. Nille, A. S. Patil, R. D. Waghmare, V. M. Naik, D. B. Gunjal, G. B. Kolekar and A. H. Gore, *Valorization of Agri-Food Wastes and By-Products*, R. Bhat, Ed. Amsterdam, Netherlands: Elsevier, 2021.

[7]. J. Ren, H.-L Wei,. L. Xu, L.-Y Jia, *Comprehensive Biotechnology*, 2nd ed., M. Moo-Young, Ed. Amsterdam, Netherlands: Elsevier, 2011.

[8]. F. Zhu, Z. Wang, J. Huang, W. Hu, D. Xie and Y. Qiao, "Efficient adsorption of ammonia on activated carbon from hydrochar of pomelo peel at room temperature: Role of chemical components in feedstock", *Journal of Cleaner Production*, vol. 406, pp. 137076, 2023.

[9]. H. Dolas, "Activated carbon synthesis and methylene blue adsorption from pepper stem using microwave assisted impregnation method: Isotherm and kinetics", *Journal of King Saud University-Science*, pp. 102559, 2023.

[10]. D. Mani, D. Elango, A. Priyadharsan, L. A. Al-Humaid, N. D. Al-Dahmash, S. Ragupathy, P. Jayanthi and Y. H. Ahn, "Groundnut shell chemically treated with KOH to prepare inexpensive activated carbon: Methylene blue adsorption and equilibrium isotherm studies", *Environmental Research*, pp. 116026, 2023.

[11]. N. A. Rosli, M. A. Ahmad and T. U. Noh, "Nature's Waste Turned Savior: Optimizing Pineapple Peel–Based Activated Carbon for Effective Remazol Brilliant Violet Dye Adsorption using Response Surface Methodology", *Inorganic Chemistry Communications*, pp. 110844, 2023.

[12]. F. Yang, C. Jin, S. Wang, Y. Wang, L. Wei, L. Zheng, H. Gu, S. S. Lam, M. Naushad, C. Li and C. Sonne, "Bamboo-based magnetic activated carbon for efficient removal of sulfadiazine: Application and adsorption mechanism", *Chemosphere*, vol. 323, pp. 138245, 2023.

[13]. H. A. S. Tohamy, N. A. Fathy, M. El-Sakhawy and S. Kamel, "Boosting the adsorption capacity and photocatalytic activity of activated carbon by graphene quantum dots and titanium dioxide", *Diamond and Related Materials*, vol. 132, pp. 109640, 2023.

[14]. S. Dandil, D. Akin Sahbaz and C. Acikgoz, "Adsorption of Cu (II) ions onto crosslinked chitosan/Waste Active Sludge Char (WASC) beads: Kinetic, equilibrium, and thermodynamic study", *International journal of biological macromolecules*, vol. 136, pp. 668-675, 2019.

[15]. M. M. A. Aslam, H. W. Kuo, W. Den, M. Sultan, K. Rasool and M. Bilal, *Separation Science and Technology*, S. Ahuja-Ahuja, Amsterdam, Ed. Netherlands: Elsevier, 2022.

[16]. J. Wang, G. Liu, T. Li and C. Zhou, "Physicochemical studies toward the removal of Zn (ii) and Pb (ii) ions through adsorption on montmorillonite-supported zero-valent iron nanoparticles", *RSC advances*, vol. 5(38), pp. 29859-29871, 2015.

[17]. J. P. Vareda, "On validity, physical meaning, mechanism insights and regression of adsorption kinetic models", *Journal of Molecular Liquids*, pp. 121416, 2023.

[18]. N. Hasani, T. Selimi, A. Mele, V. Thaci, J. Halili, A. Berisha and M. Sadiku, "Theoretical, equilibrium, kinetics and thermodynamic investigations of methylene blue adsorption onto lignite coal", *Molecules*, vol. 27(6), pp. 1856, 2022.

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Activated Charcoal Mediated Microbial Degradation of Diclofenac Using Bacterial Pure Cultures

***Aishwarya Rastogi*[1], *Manoj Kumar Tiwari*[2], *Makarand Madhao Ghangrekar*[3]**

Abstract

Diclofenac is a non-steroidal anti-inflammatory drug, commonly detected in natural aquatic environments around the world. This persistent bio-refractory emerging contaminant often occurs in concentrations of ecological significance leading to several physiological implications in living organisms. In this study, diclofenac was degraded by bacterial pure cultures isolated from soil, following which the degradation efficiency was enhanced using activated charcoal. Four bacterial strains were isolated and studied for degradation of 10 mg/L of diclofenac in the presence of acetate for 6 days. The contaminant removal was evaluated using High Performance Liquid Chromatography (HPLC). Diclofenac degradation occurred through co-metabolism with acetate acting as a supplementary carbon source. This degradation was further augmented using 1g/L commercial activated charcoal, which increases the removal efficiency through adsorption. A control consisting of only activated charcoal was also kept to check removal through adsorption without involving bacterial degradation. The control containing activated charcoal showed a removal efficiency of 71.36% through adsorption, whereas bacterial strains A, B, C, and D exhibited removal efficiencies of 86.73%, 80.83%, 77.77%, and 86.06% respectively. On combining activated charcoal with bacterial isolates, these removal efficiencies were considerably improved to 92.34%, 86.38%, 82.6%, and 93.31% respectively. This study will extend the understanding regarding the combination of two different removal methods pertaining to conventional physicochemical and biological treatment.

Keywords: Activated charcoal, bacterial degradation, diclofenac, NSAID

1. INTRODUCTION

Emerging contaminants (ECs) are environmental contaminants that are poorly understood regarding their potential for causing adverse environmental and/or human health effects. ECs encompass many classes of chemicals such as pharmaceutical and personal care products (PPCPs), fragrances and cosmetics, nanomaterials, endocrine disrupting compounds (EDCs), households and industrial chemicals which include pesticides, plasticizers (flexible plastics), fire retardants, surfactants etc. Pharmaceuticals and personal care products (PPCPs) encompass a broad class of these emerging contaminants. PPCPs have emerged as a novel class of pollutants because of their incomplete degradation in sewage treatment plants and persistence in the environment. After their metabolism, they are exposed to environment in intact as well as metabolized form, which might lead them to enter the natural food webs. Their degradation and transformation in aqueous or soil ecosystem is not always optimized and may depend on a number of variables. These emerging contaminants are a major concern for scientists nowadays as a large number of these chemicals are integrating into the

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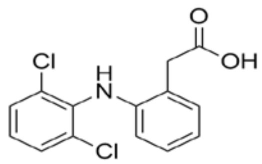
environment with known and unknown concentrations and effects. Some of these pharmaceuticals have also been found in drinking water in India. A major class of these PPCPs are Non-Steroidal Anti-Inflammatory Drugs (NSAIDs). NSAIDs are ubiquitously present in the surface waters and groundwater due to leaching which pose a disheartening situation. Due to such a widespread presence, the surface water quality as well as the aquatic life are highly affected which ultimately leads to the death and decline in number of aquatic organisms.

Among the NSAIDs, special attention is given to diclofenac because of its pervasiveness and its persistence due to its biorefractory nature. Diclofenac is a hydrophobic chlorinated compound with electron donating and withdrawing groups rendering its biological removal extremely difficult. Its ecotoxicity has been investigated on a number of model organisms. Bu et al. (2016) reviewed the varying results for persistence of diclofenac, where the half-life of diclofenac in the field was between 8 to 30 days [1]. Diclofenac was known to be the cause of rapid decline of Gyps vultures in the Indian subcontinent, because of which it was banned for use in India, Pakistan, and Bangladesh as a veterinary medicine [2]. Therefore, it is crucial to eliminate diclofenac from wastewater treatment plants and conclusively limit its exposure to living organisms. Table 1 outlines some physical properties of diclofenac.

Table 1: Properties of diclofenac (Data sourced from PubChem)

Properties	**Diclofenac**
Chemical formula	$C_{14}H_{11}Cl_{2}NO_{2}$
Chemical name	2-[2-(2,6- dichloroanilino)phenyl] acetic acid
CAS No.	15307-86-5
Chemical structure	
Molecular Weight (g/mol)	296.1
Log K_{ow}	4.51
pK_a	4.2

Physicochemical methods have conventionally been used to remove pharmaceuticals from waste water [3]. Adsorption is a physicochemical approach to remove drugs known because of its efficiency [4]. Activated carbon adsorption process has been used for removal of drugs from waste water frequently. A number of adsorbents like carbon nanotubes, clays, and biochars were developed and studied for removal of diclofenac [5]. They were reported to be efficient adsorbents for diclofenac, while raw lignocellulose was observed to be comparatively inexpensive but less efficient sorbent. Advanced oxidation process which utilizes free radical reactions was also seen as an efficient method to degrade diclofenac [6]. However, these conventional methods have disadvantages of high investment due to expensive material along with a high-energy use which results in an ecologically high carbon footprint. Therefore, the most efficient way for diclofenac removal is by biological method and is considered to be practically more reliable [7].

Bioremediation is considered as one of the most economical, sustainable, and energy-intensive approaches to eliminate contaminants from the aquatic environment. Pure bacterial cultures like *Labrys portucalensis* F11, *Pseudomonas moorei* KB4, *Pseudoxanthomonas* sp. DIN-3, and *Brevibacterium* sp. D4, have been reported to degrade diclofenac with varying degradation efficiencies [8][9][10][11]. Biotransformation of diclofenac via chemical mutagenesis has also been studied and genes like catechol 1,2-dioxygenase, protocatechuate3,4-dioxygenase, and quercetin 2,3-dioxygenase having a role in biotransformation were discovered in *Raoultella* species [12].

Biochar has been known to enhance the degradation efficiency of contaminants by elevating microbial metabolism and adsorbent properties, which makes biochar a viable supplement for biological wastewater treatment [13]. Other carbonaceous materials have also been suggested for use in tertiary water treatment where microbes are capable of immobilizing on the surface to form biofilms [14]. In our study, bacterial pure cultures isolated from soil were employed for diclofenac degradation. This degradation was further improved upon by the addition of commercial activated charcoal.

2. MATERIALS AND METHODS

2.1. Isolation of bacterial pure cultures

Bacterial pure cultures capable of degrading diclofenac were isolated from the natural soil environment using standard aseptic techniques in Nutrient Broth. 0.5 mg/L of diclofenac was used for this primary isolation of bacterial cultures, which was then incubated at 37°C for 24 hours along with the diluted soil inoculum. The bacterial consortium was spread plated on agar plates and further incubated. This was used to subculture pure bacterial cultures capable of degrading diclofenac on nutrient agar plates. With subsequent rounds of subculturing, the concentration of diclofenac was gradually increased to acclimatize the bacterial cultures to high diclofenac concentration. After 8 rounds of subculturing, the pure cultures were selectively enriched using minimal salts media and 10 mg/L diclofenac for 2 months. After the enrichment phase, the strains were centrifuged and used for further experiments.

2.2. Biodegradation of diclofenac

The isolated pure strains were screened to study their degradation pattern for 10mg/L diclofenac at 37°C for 6 days. 5.9 mM sodium acetate was added for the promotion of cell growth by producing energy and carbon polymers, which should result in an increased biodegradation of diclofenac via co-metabolism. Samples were taken at regular intervals and the bioremoval efficiency was evaluated using High Performance Liquid Chromatography (HPLC). Four bacterial isolates were selected on the basis of the highest degradation efficiency and were labelled as A, B, C and D. These strains are yet to be identified using 16S rRNA sequencing.

1g/L commercial activated charcoal was added to stimulate and enhance the bacterial degradation process through adsorption. A control consisting of only activated charcoal in 10mg/L diclofenac was also kept to check removal through adsorption without involving bacterial degradation. These tests were completely wrapped to prevent any photolytic degradation.

2.3. Diclofenac quantification using UHPLC

A Thermo Fisher Ultimate 3000 UHPLC-DAD system was used for diclofenac quantification. This was operated using a reversed phase C-18 column (Thermo Scientific). A flow rate of 1.0 mL/min with an elution time of 5 minutes and injection volume of 20 µL was used while operating at room temperature in isocratic mode. Acetonitrile and water was taken in the ratio of 60:40 as the mobile phase and diclofenac detection was carried out at 278 nm. The driver used for this chromatographic analysis was Chromaleon version 6.80.

3. RESULTS AND DISCUSSIONS

3.1. Isolation of bacterial strains

Diclofenac has been reported to be present in several water bodies globally. Continents like South America, Africa, and Asia have very high diclofenac concentrations in their rivers and lakes. Usually, these concentrations lie below 10 µg/L [15]; however, incredibly high concentrations have also been observed in some instances. Beberibe river (Brazil) showed usual diclofenac concentration of 193 µg/L [16]. Figure 1 demonstrates the diclofenac concentrations found in water bodies globally.

<0.1 µg/L 0.1-0.5 µg/L 0.5-1.0 µg/L

1.0-10.0 µg/L 10.0-20.0 µg/L >20.0 µg/L

Figure 1 demonstrates the diclofenac concentrations found in water bodies globally

An even higher concentration of 0.203 mg/L and 0.721 mg/L were found in wastewater treatment plants in Korea and Mangalore (India) respectively [17][18]. Keeping these high concentrations in mind, 0.5 mg/L diclofenac was used for primary bacterial consortium isolation. Figure 2 shows the bacterial consortia isolated from soil capable of degrading diclofenac.

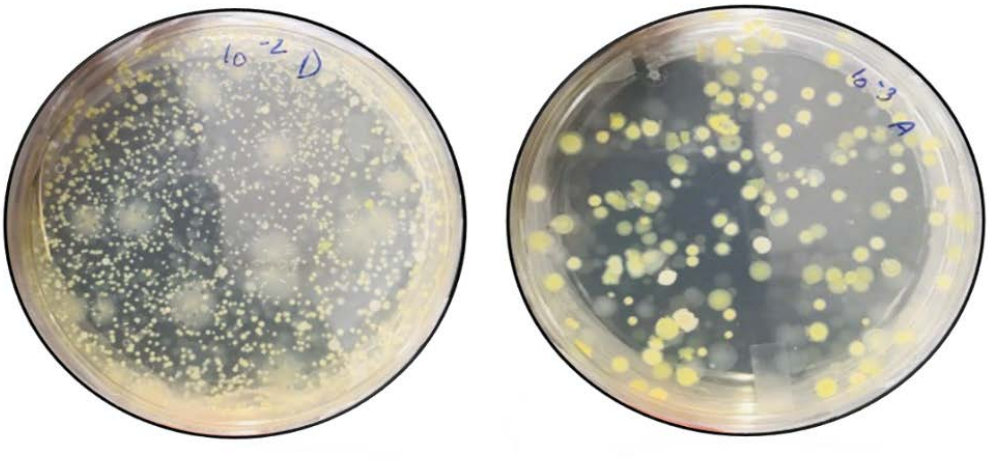


Figure 2. Bacterial consortia isolated from soil capable of degrading diclofenac

The pure bacterial strains were isolated based on the different bacterial morphology. The selective pressure created by the constant presence of diclofenac upregulated the enzymes necessary for diclofenac degradation [19]. Since diclofenac is a highly biorefractory drug, it has often shown very low biodegradation in wastewater treatment plants [20]. Because of this low biodegradability, an extended enrichment period of 3 months was used for the acclimatization of bacterial strains to high diclofenac concentrations.

3.2. Biodegradation of diclofenac using bacterial pure cultures and activated charcoal

The biodegradation efficiencies were tested for all the isolated bacterial strains. The bioremoval was facilitated through co-metabolism using acetate as a supplementary carbon source. The control containing activated charcoal showed a removal efficiency of 71.36% through adsorption, whereas bacterial strains A, B, C, and D exhibited removal efficiencies of 86.73%, 80.83%, 77.77%, and 86.06% respectively. In other studies, fungal cultures of *Trametes versicolor* was found capable of degrading 94% of 10 mg/L diclofenac as a sole carbon source in just 1 hour [21]. On the other hand, *Enterobacter cloacae D16* degraded 67.57% of the same diclofenac concentration in 48 hours [22]. However, *Brevibacterium* sp. D4 degraded 90% of 10 mg/L diclofenac with periodic supplementary feeding with acetate in 30 days [11], which was similar to our study.

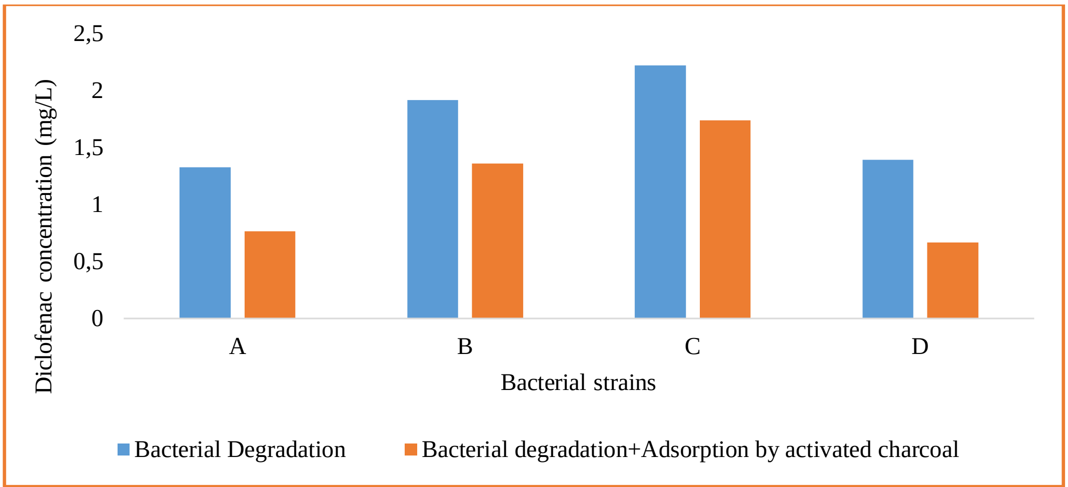


Figure 3. Degradation efficiencies of isolated bacterial strains

Moreover, the time taken by our bacterial strains was comparatively lower than *Brevibacterium sp. D4*. The removal efficiencies and the time taken depends mainly on the bacterial strains used for degradation.

On combining activated charcoal with bacterial isolates, these removal efficiencies were considerably improved to 92.34%, 86.38%, 82.6%, and 93.31% respectively. This increase was in accordance with literature [13]. Figure 3 showcases the degradation efficiencies of different bacterial strains for 10 mg/L diclofenac in both these cases. Figure 4 demonstrates the degradation pattern of 10 mg/L diclofenac using all the bacterial strains, which showed the highest removal efficiencies after the addition of activated charcoal. Highest degradation was achieved by combining activated charcoal along with strain D. A detail worth noticing was that the degradation in the case of combined activated charcoal and bacterial species on day 4 exceeded the degradation in the case of bacterial degradation on day 6.

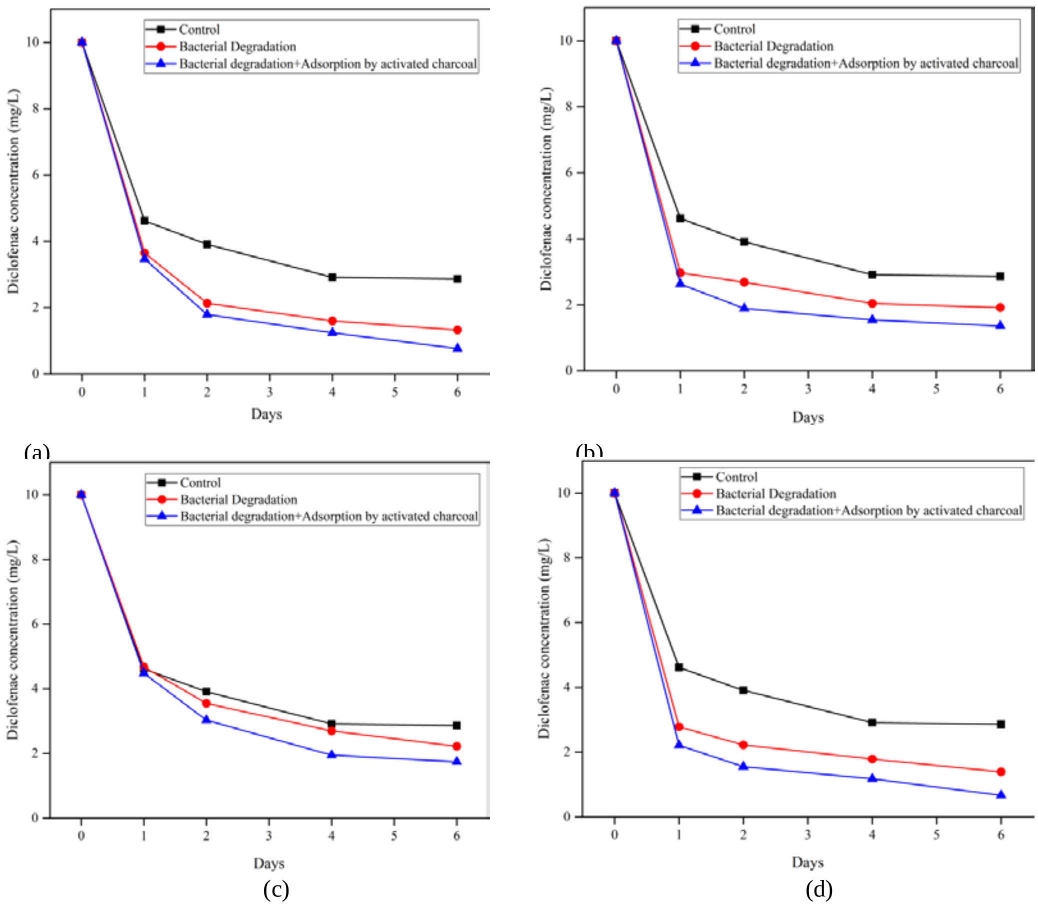


Figure 4. Degradation patterns of bacterial strains (a) A, (b) B, (c) C, and (d) D

CONCLUSIONS

Diclofenac, being an emerging contaminant and a micropollutant is very difficult to degrade using energy and cost-effective technique. Therefore, microbial degradation is viewed as a feasible solution to this problem. In our study, 4 bacterial strains capable of degrading diclofenac were isolated from soil samples. Activated charcoal showed a removal efficiency of 71.36% through adsorption, whereas biodegradation using bacterial strains A, B, C, and D yielded removal efficiencies of 86.73%, 80.83%, 77.77%, and 86.06% respectively.

These removal efficiencies were considerably improved to 92.34%, 86.38%, 82.6%, and 93.31% respectively on integrating activated charcoal with bacterial isolates. The degradation rate also improved on integrating the two techniques as was evident by the fact that the removal in the case of combined activated charcoal and bacterial species on day 4 exceeded the removal in the case of bacterial degradation on day 6.

This study will help in augmenting the knowledge of microbial degradation of a biorefractory drug diclofenac. Moreover, this study will extend the understanding regarding the combination of two different removal methods pertaining to conventional physicochemical and biological treatment. Following the identification of bacterial species and their morphology, another study involving the interaction of activated charcoal with the surface of bacterial colonies will further help in establishing a direct synergistic relationship with the former. Although this process poses some concerning disadvantages regarding the disposal of activated charcoal after contaminant degradation, it is worth exploring due to an increased removal efficiency and reduced retention time.

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REFERENCES

[1] Q. Bu, X. Shi, G. Yu, J. Huang, and B. Wang, “Assessing the persistence of pharmaceuticals in the aquatic environment: Challenges and needs,” Emerging Contaminants, vol. 2, pp. 145-147, 2016.

[2] J.L. Oaks, M. Gilbert, M.Z. Virani, R.T. Watson, C.U. Meteyer, B.A. Rideout, H.L. Shivaprasad, S. Ahmed, M.J.I. Chaudhry, M. Arshad, S. Mahmood, A. Ali, and A. Ahmed, “Diclofenac residues as the cause of population decline in Pakistan,” Nature, vol.427, pp. 630-633, 2004.

[3] A.G. Capodaglio, A. Bojanowska-Czajka, and M. Trojanowicz, “Comparison of different advanced degradation processes for the removal of the pharmaceutical compounds diclofenac and carbamazepine from liquid solutions,” Environ Sci Pollut Res, vol. 25, pp. 27704-27723, 2018.

[4] J.G. Yu, X.H. Zhao, H.Yang, X.H. Chen, Q. Yang, L.Y. Yu, J.H. Jiang, and X.Q. Chen, “Aqueous adsorption and removal of organic contaminants by carbon nanotubes,” Science of The Total Environment, vol. 482–483, pp. 241-251, 2014. https://doi.org/10.1016/j.scitotenv.2014.02.129.

[5] J.L. Sotelo, A.R. Rodríguez, M.M. Mateos, S.D. Hernández, S.A. Torrellas, and J.G. Rodríguez, “Adsorption of pharmaceutical compounds and an endocrine disruptor from aqueous solutions by carbon materials,” Journal of Environmental Science and Health, Part B, vol. 47:7, pp. 640-652, 2012. DOI: 10.1080/03601234.2012.668462.

[6] Z. Wang, V. Srivastava, I. Ambat, Z. Safaei, and M. Sillanp¨a¨a, “Degradation of ibuprofen by UV-LED/catalytic advanced oxidation process,” Journal of Water Process Engineering, vol. 31, pp. 100808, 2019.

[7] F.P. Shariati, M.R. Mehrnia, B.M. Salmasi, M. Heran, C. Wisniewski, and M.H. Sarrafzadeh, “Membrane bioreactor for treatment of pharmaceutical wastewater containing acetaminophen,” Desalination, vol. 250, pp. 798-800, 2010. https://doi.org/10.1016/j.desal.2008.11.044.

[8] I.S. Moreira, V.S. Bessa, S. Murgolo, C. Piccirillo, G. Mascolo, and P.M.L. Castro, “Biodegradation of diclofenac by the bacterial strain *Labrys portucalensis* F11,” Ecotoxicology and Environmental Safety, vol. 152, pp. 104–113, 2018.

[9] Z. Lu, W. Sun, C. Li, X. Ao, C. Yang, and S. Li, “Bioremoval of non-steroidal anti-inflammatory drugs by *Pseudoxanthomonas* sp. DIN-3 isolated from biological activated carbon process,” Water Research vol. 161, pp. 459-472, 2019.

[10] J. Z˙ur, A. Pin´ski, D. Wojcieszyn´ska, W. Smułek, and U. Guzik, “Diclofenac Degradation—Enzymes, Genetic Background and Cellular Alterations Triggered in Diclofenac-Metabolizing Strain *Pseudomonas moorei* KB4,” Int. J. Mol. Sci. 21, 6786, 2020. doi:10.3390/ijms21186786.

[11] V.S. Bessa, I.S. Moreira, M.E. Tiritan, and P.M.L. Castro, “Enrichment of bacterial strains for the biodegradation of diclofenac and carbamazepine from activated sludge. International Biodeterioration & Biodegradation,” vol. 120, pp. 135-142, 2017.

[12] A. Palyzova, J. Zahradnik, H. Marešova, and T. Řezanka, "Characterization of the catabolic pathway of diclofenac in *Raoultella* sp. KDF8," International Biodeterioration & Biodegradation, vol. 137, pp. 88–94, 2019.

[13] A. Jayakumar, C. Wurzer, S. Soldatou, C. Edwards, L.A. Lawton, and O. Mašek, "New directions and challenges in engineering biologically-enhanced biochar for biological water treatment," Science of The Total Environment, vol. 796, pp. 148977, 2021. https://doi.org/10.1016/j.scitotenv.2021.148977.

[14] F. Cecen, and O Aktas, "Activated Carbon for Water and Wastewater Treatment: Integration of Adsorption and Biological Treatment," 388 pages, ISBN: 978-3-527-32471-2, Wiley-VCH, 2011.

[15] A. Rastogi, M.K. Tiwari, and M.M. Ghangrekar, "A review on environmental occurrence, toxicity and microbial degradation of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)," Journal of Environmental Management, vol. 300, pp. 113694, 2021.

[16] T.B. Veras, A.L.R. de Paiva, M.M.M.B. Duarte, D.C. Napoleao, and J.J.S.P Cabral, "Analysis of the presence of anti-inflammatories drugs in surface water: a case study in Beberibe river - PE, Brazil," Chemosphere, vol. 222, pp. 961–969, 2019.

[17] W.J. Sim, J.W. Lee, E.S. Lee, S.K. Shin, S.R. Hwang, and J.E. Oh, "Occurrence and distribution of pharmaceuticals in wastewater from households, livestock farms, hospitals and pharmaceutical manufactures," Chemosphere, vol. 82, pp. 179–186, 2011.

[18] A.K. Thalla and A.S. Vannarath, "Occurrence and environmental risks of nonsteroidal anti-inflammatory drugs in urban wastewater in the southwest monsoon region of India." Environ. Monit. Assess. vol. 192, pp. 193, 2020.

[19] O.A.H. Jones, N. Voulvoulis, and J.N. Lester, "The occurrence and removal of selected pharmaceutical compounds in a sewage treatment works utilising activated sludge treatment," Environmental Pollution, vol. 145, pp. 738-744, 2007.

[20] N. Vieno, and M. Sillanpää, "Fate of diclofenac in municipal wastewater treatment plant— A review.' Environ. Int. Vol. 69, pp. 28–39, 2014.

[21] E. Marco-Urrea, M. Pérez-Trujillo, C. Cruz-Morató, G. Caminal and T. Vicent, "Degradation of the drug sodium diclofenac by *Trametes versicolor* pellets and identification of some intermediates by NMR," Journal of Hazardous Materials, vol. 176, pp. 836–842, 2010.

[22] S. Aissaoui, M. Sifour, H. Ouled-Haddar, L. Benguedouar, and M. Lahouel, "Toxicity assessment of diclofenac and its biodegradation metabolites toward mice," Toxicol. Environ. Health. Sci. Vol. 9, pp. 284–290, 2017.

BIOGRAPHY

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Investigation of the Effect of Ionic Liquid based Chitosan on Color Removal from Textile Wastewater

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Abstract

Sustainable wastewater management is a significant issue to overcome water shortage problem. In this context, it is very important to manage industrial wastewater properly. The textile industry is one of the most water consuming industry and huge amount of colored toxic wastewater is produced during the production of textile products. One of the most environmentally damaging stages in textile production is dyeing process. In some studies, it is stated that textile finishing and dyeing processes cause 20% of all freshwater pollution. Various treatment methods including physicochemical, chemical, and biological techniques are used for the color removal in the textile wastewater. Adsorption is one of the most effective methods of color removal and natural biopolymers like chitosan have great attractive as eco-friendly and low-cost sorbents.Within the scope of the study, an imidazolium based ionic liquid was synthesized and the sorbent obtained by interacting this synthesized ionic liquid with chitosan was used for the removal of Reactive Black 5 dye. Ionic liquids are known as green solvents and their applications in wastewater treatment are quite new. In this study, chitosan saturated with 0.25 g ionic liquid, which is 1,4-bis(3-methylimidazolium) butane di[bis(trifluoromethylsulfonyl)imide], was used as sorbent. Adsorption experiments were carried out using a batch system. Removal efficiencies were investigated at different pH (5, 6, 7, 8, and 9) and different mixing times (10, 30, 60, 90, and 120 minutes) by adding 250 mg ionic liquid-based sorbent to the 50 mL of wastewater sample containing dye into the beaker placed on a mixer. RES method was used for color measurements. As a result of the study, higher than 99% removal efficiencies were achieved at all operational conditions. The optimum operating conditions were determined as pH 5 and mixing time of 10 minutes.

Keywords: Adsorption, chitosan, color, ionic liquid, sorbent, textile

1. INTRODUCTION

1.1. *Wastewater Production in Textile Industry*

In the textile industry, depending on the amount of water consumed in production and the chemicals used, a large amount of wastewater with a high chemical load is generated. When the whole life cycle of a textile product is examined, it is seen that a lot of water is consumed in all stages from raw material production to textile production and use of the textile product. Water is used for cleaning the raw material and for many washing steps throughout the entire production process. In order to produce 1 kg of textile, approximately 200 L of water is used [1].

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In textile production, water consumption per unit production varies according to fiber type, equipment type and working conditions. Water is mainly used in bleaching, finishing and dyeing processes. As a matter of fact, it has been determined that 38% of the water is used in bleaching, 16% in dyeing, 8% in printing, 14% in boilers and 24% in other uses. As a result of these processes, a significant amount of wastewater is released. An average of 90-95% of the water consumed in the factory turns into waste water. The fact is that the volume of wastewater from textile production is huge and contains large quantities of environmentally harmful dyes and other chemicals [2].

Different types of wastewater are produced in each textile factory, depending on the type of product produced and the chemicals used. However, in general, wastewaters with high pH values, high organic matter, suspended and dissolved solids, dye and trace metals such as manganese and lead copper are formed [3].

1.2. *Ionic Liquids*

Ionic liquids (ILs) are organic salts that exist as liquids at low temperatures, usually below 100 °C, and are considered an environmentally friendly solvent option. With further advances in advanced materials calculation and analytical measurement techniques that can effectively predict the behavior and properties of ionic liquids at room temperature, research into the application of ionic liquids has increased. In addition to the rapid developments in solid state physics and optoelectronic technology and their benefits in the liquid-liquid extraction process, ionic liquids find use in electrochemical storage devices, low temperature applications, sensors and smart instrumentation. There is an almost unlimited combination of anions and cations that can be used to synthesize ionic liquids, and therefore there is an opportunity to be used in different fields [4]. The use of ionic liquids for the removal of dyes, metal ions, organics and other contaminants from domestic and industrial wastewater has been extensively reported in the literature [5].

1.3. *Ionic Liquids in Wastewater Treatment*

When the literature on the use of ionic liquids in wastewater treatment is examined, it is seen that studies on this subject have become widespread, especially as of 2010. Although there are some studies in laboratory conditions, its use on a full scale is very limited. Ionic liquids can be used for the selective treatment and recovery of many organic pollutants such as dyes, amines, herbicides, toluene, PAHs, phenolic compounds. In the studies, mainly adsorption and liquid-liquid extraction methods using ionic liquid-based adsorbent materials were used. Ionic liquids are defined as compounds that are normally composed entirely of ions and have a melting point below 100 °C. The most relevant properties of ionic liquids are their almost negligible vapor pressures. Because of these properties, ionic liquids are considered as alternative green solvents to volatile organic solvents [5].

Ionic liquids have been applied as solvent systems in chemical reactions, separations, extractions, electroanalytical applications, and chemical sensing.

2. MATERIAL AND METHODS

The experimental studies were carried out with synthetic water. In order to have 1 L synthetic dyed wastewater, 100 mg color agent (Reactive Black 5) and 1 L distilled water was mixed.

The batch adsorption experiments were conducted in 100 mL-beakers. 50 mL of dye solution was added in each beaker and chitosan saturated with 0.25 g 1,4-bis(3-metilimidazolium)butane di[bis(triflorometilsulphonil)imid] was added as an adsorbent for the removal of color from synthetic water. The structure of ionic liquid, which is 1,4-bis(3-metilimidazolium)butane di[bis(triflorometilsulphonil)imid], is seen in Figure 1.

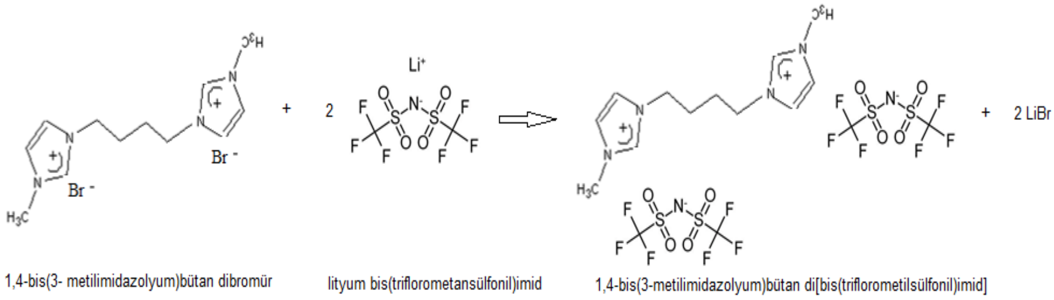

Figure 1. 1,4-bis(3-metilimidazolyum)butan di[bis(triflorometilsulfonil)imid]

Constant stirring was applied in a magnetic stirrer at 350 rpm and experiments were performed at 25 °C. Color removal efficiencies were monitored at various pH and mixing time. Applied operational conditions are given in Table 1.

Table 1. Applied operational conditions

Mixing time (minutes)	10 – 30 – 60 – 90 – 120
pH	5 – 6 – 7 – 8 – 9
Sorbent	250 mg/50 mL

3. RESULTS AND DISCUSSION

The color was measured at three different wavelengths (436, 535, and 620 nm) in the spectrophotometer and the results at 436 nm wavelength were taken into account according to the color studied. The obtained results are given as absorbance values in tables and treatment efficiencies as graphs. Absorbance values and color removal efficiencies obtained at 120, 90, 60, 30 and 10 min mixing times are given in Table 2, 3, 4, 5, and 6 and Figure 2, 3, 4, 5, and 6, respectively.

Table 2. Absorbance values for 120-minute mixing

Wavelength	pH					Raw
	5	6	7	8	9	
436	0.0187	0.0198	0.0161	0.0198	0.0199	0.6822
525	0.0147	0.0149	0.0149	0.0144	0.0152	1.2102
620	0.0143	0.0127	0.0127	0.0118	0.0142	2.4775

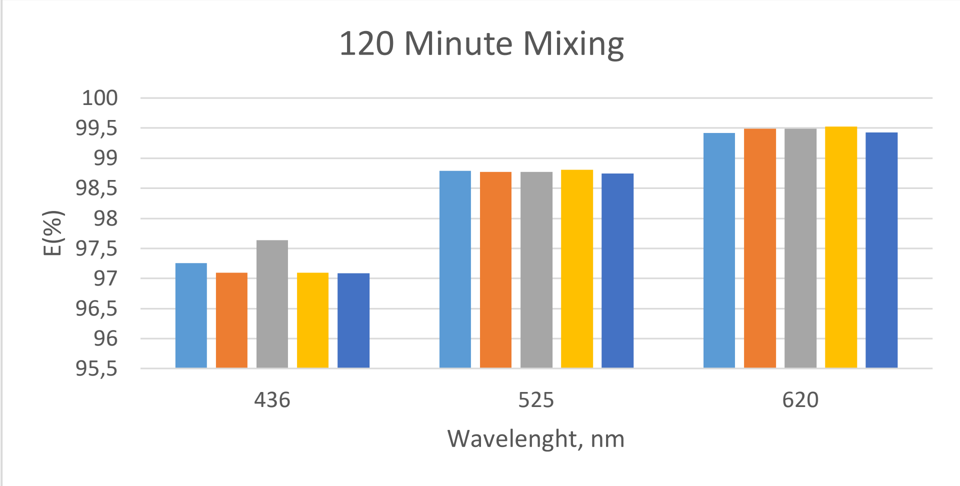

Figure 2. Color removal efficiencies at 120-minute mixing time

Table 3. Absorbance values for 90-minute mixing

Wavelength	pH					Raw
	5	6	7	8	9	
436	0.0117	0.0109	0.0108	0.0102	0.0126	0.6822
525	0.0089	0.0074	0.0073	0.0067	0.0081	12.102
620	0.0077	0.0065	0.0062	0.0057	0.0065	24.775

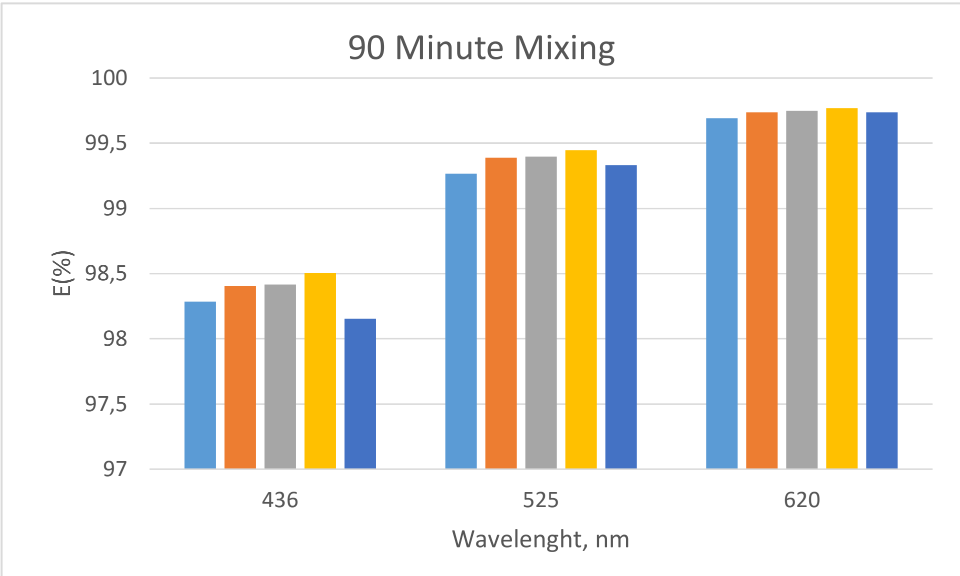

Figure 2. Color removal efficiencies at 90-minute mixing time

Table 3. Absorbance values for 60-minute mixing

Wavelength	pH					Raw
	5	6	7	8	9	
436	0.0047	0.006	0.008	0.0107	0.011	0.6822
525	0.0029	0.003	0.0039	0.0071	0.0074	12.102
620	0.0025	0.0026	0.0034	0.0073	0.0088	24.775

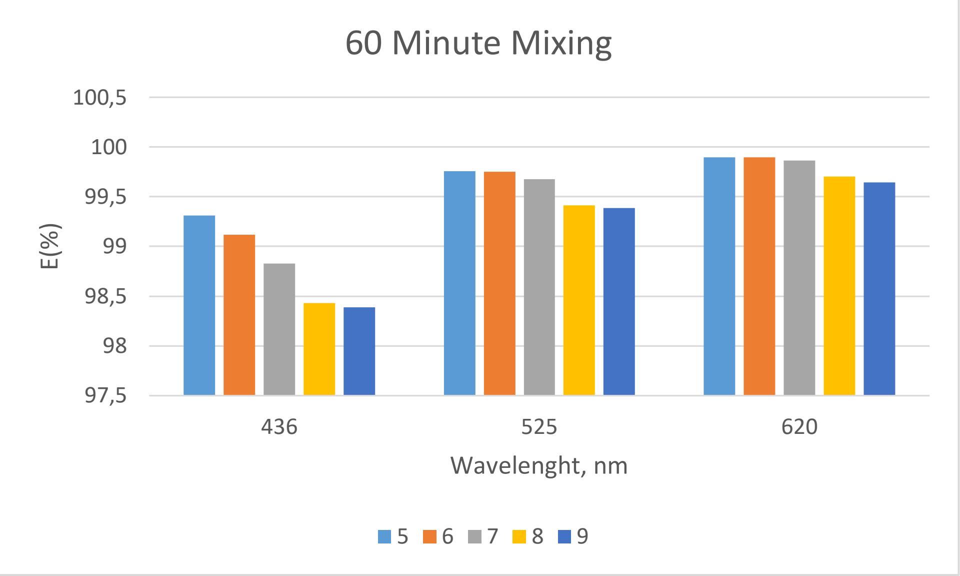

Figure 3. Color removal efficiencies at 60-minute mixing time

Table 4. Absorbance values for 30-minute mixing

Wavelength	pH					Raw
	5	6	7	8	9	
436	0.0047	0.0183	0.0503	0.0447	0.0696	0.6822
525	0.0014	0.0197	0.0775	0.0677	0.1643	12.102
620	0.0018	0.0276	0.1424	0.1201	0.3148	24.775

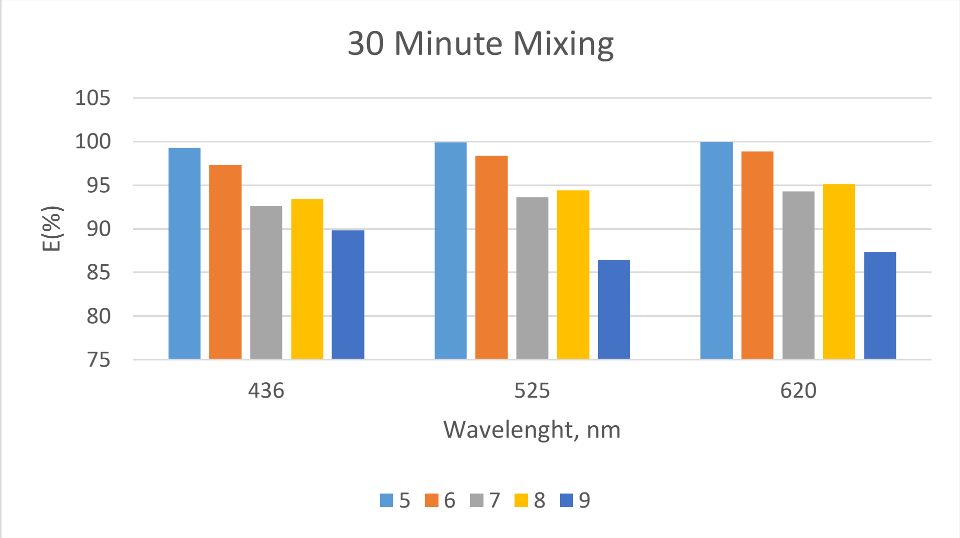

Figure 4. Color removal efficiencies at 30-minute mixing time

Table 5. Absorbance values for 10-minute mixing

Wavelength	pH					Raw
	5	6	7	8	9	
436	0.0024	0.0692	0.1247	0.1355	0.1063	0.6822
525	0.001	0.1063	0.212	0.2343	0.1771	12.102
620	0.0026	0.1971	0.4157	0.4674	0.3415	24.775

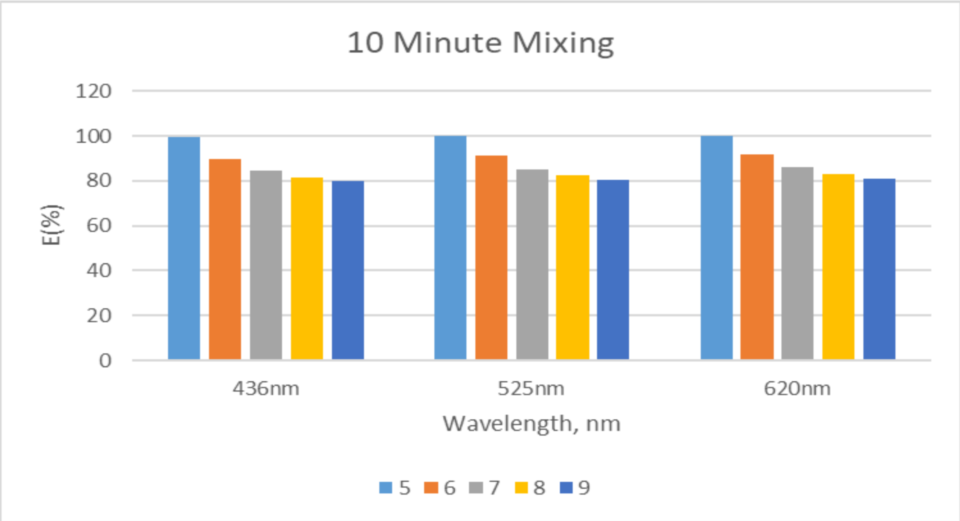

Figure 5. Color removal efficiencies at 10-minute mixing time

4. CONCLUSIONS

In accordance with this study, the following conclusions were obtained:

- Almost the same efficiencies were obtained at mixing times of 60, 90, and 120 minutes.
- In the experiments where mixing times of 10 and 30 minutes were applied, better results were obtained at pH 5 than those obtained at other pH values.
- Optimum conditions were determined as pH 5 and mixing time of 10 minutes (E = 99.6%).
- Experimental studies continue under different operating conditions. Within the scope of this paper, the results of the first experiments are presented.

REFERENCES

[1]. Kaplan, B. E. (2019). Tekstil terbiye atik suyunda manyetik polimerlerle renk giderimi (Doctoral dissertation, Bursa Uludag University (Turkey)).

[2]. Antoniewicz, P. (2021, May 29). Understanding and coping with struvite/vivianite formation in wwtps. Water Online. https://www.wateronline.com/doc/understanding-and-coping-with-struvite-vivianite-formation-in-wwtps-0001.

[3]. Albomahdi, H. M. I. (2022). Adsorption of brilliant blue dye by amberlite IR120/Agaricus campestris biomaterial; the perform of some adsorption isotherm on the process (Master degree dissertation, Van Yuzuncu Yil University (Turkey).

[4]. Goutham, R., Rohit, P., Vigneshwar, S. S., Swetha, A., Arun, J., Gopinath, K. P., & Pugazhendhi, A. (2022). Ionic liquids in wastewater treatment: A review on pollutant removal and degradation, recovery of ionic liquids, economics and future perspectives. Journal of Molecular Liquids, 349, 118150.

[5]. Khraisheh, M., AlMomani, F., Inamdar, M., Hassan, M. K., & Al-Ghouti, M. A. (2021). Ionic liquids application for wastewater treatment and biofuel production: A mini review. Journal of Molecular Liquids, 337, 116421.

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Environmental Effects of Using Renewable Energy in the Production of Recycled Fiber from Textile Scraps

Irem Kilic[1], Nurdan Buyukkamaci[2], Ahmet Sengulen[1], Sema Bahar Erdem[1]

Abstract

The textile industry has large impacts on the environment for reasons such as the high use of chemicals and water on production processes, the disposal of wastes generated during production by incineration or transferring them to landfills. Cotton is one of the most used fibers and cotton cultivation also have negative impact for the environment since cotton grown needs large agricultural land and the use of water and pesticides. Therefore, recycling is an issue that should be given importance for reducing the environmental impact of the cotton textile industry and for a more sustainable production.

Obtaining recycled fibers from textile scraps and producing textile products from these recycled fibers is an important application in terms of sustainable textile production. In this study, it was aimed to determine the environmental effects in case of using grid electricity and solar energy in the phase of obtaining fiber from textile scraps. Within the scope of the study, environmental effects were determined by life cycle analyses approach. The required data was obtained from a recycling company in Usak. The company uses electricity in the production and the current environmental effects of the production was determined by using their operational input and output values. As a more environmentally friendly application, the use of solar energy instead of grid electricity has been evaluated as a scenario. GaBi software was used for LCA study and the results were evaluated according to the CML impact categories.

The results reveal that production with solar energy has lower impacts compared to electricity. According to results, there has been about 95% reduction in global warming potential. At almost all CML impact categories except the categories of abiotic depletion and ozone layer depletion potential, solar energy results lower effects than electricity.

Keywords: LCA, textile industry, sustainability

1. INTRODUCTION

1.1. *Textile Industry*

Due to the population growth and the rapid development of fashion, there is an increase in the production and consumption of textile products. Recycling is becoming an important issue all over the world due to reasons such as conservation of resources in textile products and processes, the need to reduce waste areas, the cost of waste and the need for cheap raw materials for production [1].

The production flow chart of the textile and apparel industry is seen in Figure 1. The raw material coming to the facility passes through certain stages and is turned into yarn. After the yarn production, the fabric is obtained by the knitting process. Fabrics are used in the production of the desired product and reach the consumer.

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Figure 1. Textile and garment manufacturing production flow chart [2].

The second most polluting sector in the world after the oil industry, which causes about 1 billion tons of greenhouse gas emissions, is textile industry. It is estimated that 25% of the world's carbon budget will be used by the fashion industry by 2050 [3].

Countries, national and international organizations, consumers and manufacturers who are aware of the environmental damage of the textile industry continue to work intensively on recycling [1].

1.2. *Cotton Production*

Cotton is one of the most used fibers in the textile industry. Cotton cultivation has significant environmental impacts due to reasons such as high water consumption, land occupation, energy, fertilizer and pesticide use, which may harm the environment and human health [4]. For this reason, providing cotton fiber from recycled fibers is an significant issue for reducing the environmental impact of the cotton textile industry and for a more sustainable production.

1.3. *Life Cycle Assessment*

Life Cycle Assessment (LCA) is a scientific and standardized methodology with ISO 14040. LCA is used to calculate the environmental impacts of a product's raw material during the stages of obtaining, production, transportation, use and disposal, and to identify the problematic points of production and get to the source of the problems [5].

The LCA methodology is widely used in the textile industry to evaluate different aspects and life cycle stages of products, from raw material cultivation and fiber production to fabric processing and disposal of used products [6].

2. MATERIAL METHODS

In this study, the life cycle assessment of recycled scrap fabrics was made. Data were obtained from a pilot facility located in Usak, Turkey. According to the data obtained, the type of energy used by the pilot facility in production is electricity.

First of all, the environmental effects of using electricity in the recycling process were examined. Then, the effects of the scenario created for the use of solar energy, which is a renewable energy type, in production were examined. By comparing these two scenarios, the effect of energy type on the environmental effects of recycled fiber production was investigated.

LCA studied were carried out with GaBi software (Sphera Company). The results were analyzed according to the CML effect categories.

3. RESULTS AND DISCUSSIONS

3.1. *Scenario 1: Recycled Cotton Fiber Production with Electricity*

According to the data received from the pilot facility, a flow chart was created in the GaBi software. Recycled cotton fiber production flow chart is seen in Figure 2.

The process steps are as follows;

- Initially, the scrap fabrics are sorted according to their colors and fiber types.
- Then the fabrics are get smaller with the cutting machine.
- As the next step, the fabrics are turn into fibers with the rag pulling machine.
- Final step, the fibers pressed and baled.

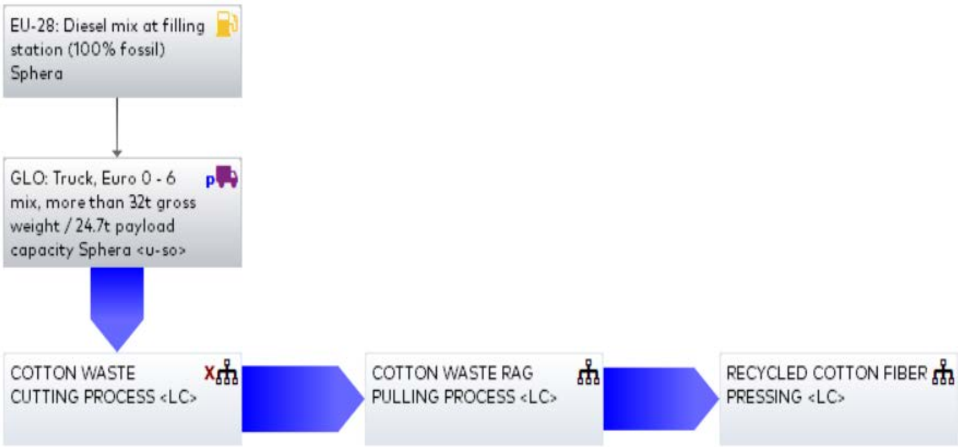

Figure 2. Scenario 1 flow chart

Table 1 shows the effect of each process of Scenario 1 according to the CML categories. The values show that the highest effect in all categories is due to the rag pulling process. The percentage of the results given in the table on the impact categories of each process is shown in Figure 3.

Table 1. LCA results of Scenario 1

CML2001 - Aug. 2016	TOTAL	COTTON WASTE CUTTING PROCESS	COTTON WASTE RAG PULLING PROCESS	RECYCLED COTTON FIBER PRESSING	Diesel mix at filling station (100% fossil)	Transport
Abiotic Depletion (ADP elements) [kg Sb eq.]	1.32E-07	1.64E-08	9.50E-08	1.95E-08	1.19E-09	-
Abiotic Depletion (ADP fossil) [MJ]	27.4	3.4	19.6	4.04	0.308	-
Acidification Potential (AP) [kg SO2 eq.]	0.0283	0.00355	0.0205	0.00422	1.10E-05	1.67E-05
Eutrophication Potential (EP) [kg Phosphate eq.]	8.23E-04	1.03E-04	5.93E-04	1.22E-04	1.30E-06	4.64E-06
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	0.00223	2.67E-04	0.00154	3.17E-04	1.05E-04	3.13E-08
Global Warming Potential (GWP 100 years) [kg CO2 eq.]	2.38	0.296	1.71	0.352	0.00306	0.0195
Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	2.38	0.296	1.71	0.352	0.00306	0.0186
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	0.293	0.0367	0.212	0.0437	3.94E-04	2.47E-05
Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	1550	195	1120	231	0.397	6.24E-09
Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.39E-11	1.74E-12	1.01E-11	2.07E-12	2.66E-15	-
Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	0.00387	4.84E-04	0.00279	5.75E-04	2.07E-05	3.56E-09

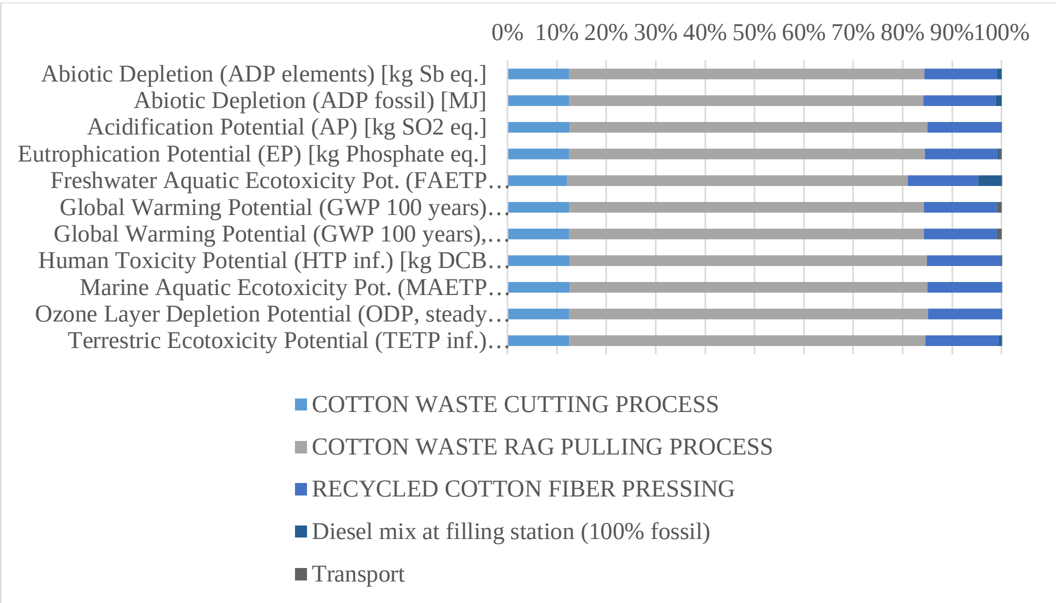

Figure 3. Percentage distribution of results for Scenario 1

3.2. *Scenario 2: Recycled Cotton Fiber Production with Solar Energy*

In this scenario, a new flow chart was created by replacing the energy type used by the pilot plant in production with solar energy, and a life cycle assessment was made. The process steps are the same as in the previous scenario, only the energy type has been changed.

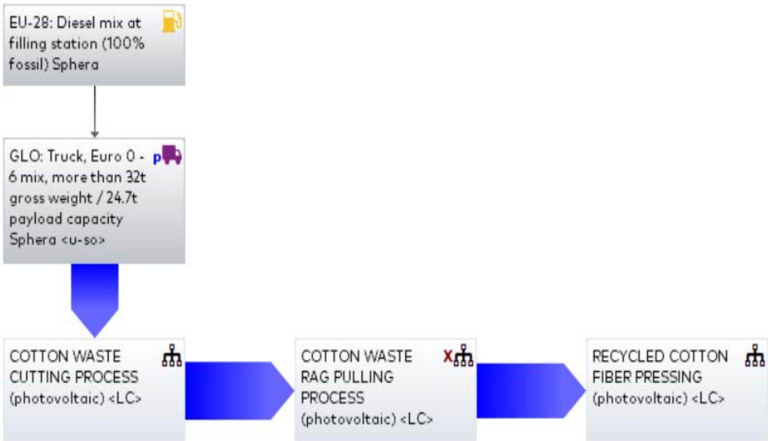

Figure 4. Scenario 2 flow chart

The LCA results of this scenario are seen in Table 2. As in the previous scenario, the rag pulling process has the most impact. It has been determined that this process causes about five times more effect than other processes.

The percentage of the results given in the table on the impact categories of each process is shown in Figure 5.

Table 2. LCA results of Scenario 2

CML2001 - Aug. 2016	TOTAL	COTTON WASTE CUTTING PROCESS	COTTON WASTE RAG PULLING PROCESS	RECYCLED COTTON FIBER PRESSING	Diesel mix at filling station (100% fossil)	Transport
Abiotic Depletion (ADP elements) [kg Sb eq.]	6.84E-06	8.58E-07	4.96E-06	1.02E-06	1.19E-09	-
Abiotic Depletion (ADP fossil) [MJ]	1.47	0.146	0.843	0.174	0.308	-
Acidification Potential (AP) [kg SO2 eq.]	4.14E-04	4.85E-05	2.80E-04	5.76E-05	1.10E-05	1.67E-05
Eutrophication Potential (EP) [kg Phosphate eq.]	4.48E-05	4.87E-06	2.82E-05	5.80E-06	1.30E-06	4.64E-06
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5.81E-04	5.98E-05	3.45E-04	7.11E-05	1.05E-04	3.13E-08
Global Warming Potential (GWP 100 years) [kg CO2 eq.]	0.129	0.0133	0.077	0.0158	0.00306	0.0195
Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	0.128	0.0134	0.0775	0.0159	0.00306	0.0186
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	0.0195	0.0024	0.0138	0.00285	3.94E-04	2.47E-05
Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	46.6	5.8	33.5	6.89	0.397	6.24E-09
Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	4.66E-10	5.84E-11	3.38E-10	6.95E-11	2.66E-15	-
Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	0.00124	1.53E-04	8.85E-04	1.82E-04	2.07E-05	3.56E-09

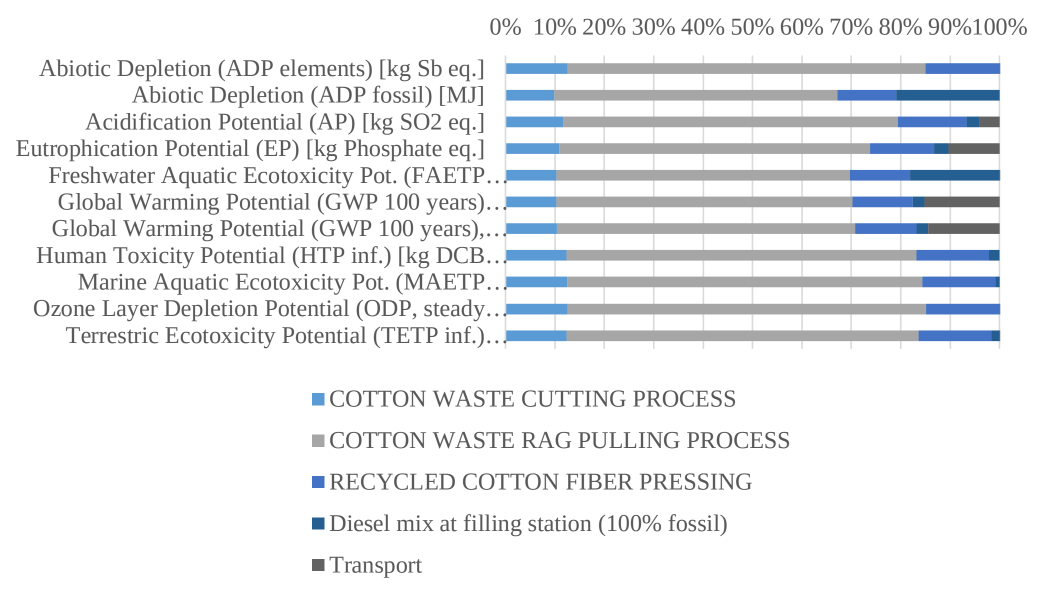

Figure 5. Percentage distribution of results for Scenario 2

3.3. *Comparison of Generated Scenarios*

The environmental effects determined in the case of using electricity and solar energy in the process of obtaining recycled fiber from scrap fabrics are shown in Table 3 comparatively. As expected, the impact of solar energy, which is one of the renewable energy sources, is much less than electricity. The positive changes identified in most of the impact categories were greater than 90%.

Negative values in the table represent the negative impact of the application on the environment. Accordingly, for the abiotic depletion and ozone depletion potential categories, worse results were obtained when solar energy was used. It is thought that this is due to the additional environmental effects that occur during the production of solar panels.

Table 3. Comparison of Scenario 1 and Scenario 2

CML2001 - Aug. 2016	ELECTRICITY	SOLAR ENERGY	CHANGES
Abiotic Depletion (ADP elements) [kg Sb eq.]	1.32E-07	6.84E-06	-98%
Abiotic Depletion (ADP fossil) [MJ]	27.4	1.47	95%
Acidification Potential (AP) [kg SO2 eq.]	0.0283	4.14E-04	99%
Eutrophication Potential (EP) [kg Phosphate eq.]	8.23E-04	4.48E-05	95%
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	0.00223	5.81E-04	74%
Global Warming Potential (GWP 100 years) [kg CO2 eq.]	2.38	0.129	95%
Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	2.38	0.128	95%
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	0.293	0.0195	93%
Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	1550	46.6	97%
Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.39E-11	4.66E-10	-97%
Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	0.00387	0.00124	68%

4. CONCLUSION

Although cotton fiber is seen as an environmentally friendly product because it is a natural fiber, it is known that it has a very negative impact on the environment due to applications such as excessive water use, fertilizer and pesticide use during cotton production when examined throughout its life cycle. For this reason, it is an important practice to obtain recycled fiber from waste fabrics, both for the evaluation of waste and for reducing the consumption of raw cotton. However, environmental effects also occur due to the energy consumed by the equipment used in the recycling processes, and if renewable energy sources are used in these enterprises, there will be much more sustainable textile production. This issue has also been proved numerically by the LCA studies, the results of which are presented within the scope of this paper. It has been observed that the use of solar energy instead of electricity in the production of recycled fiber has less impact on the environment.

REFERENCES

[1]. Turemen, M., Demir, A., & Ozdogan, E. (2019). Tekstil endustrisi icin geri donusum ve onemi. Pamukkale Universitesi Muhendislik Bilimleri Dergisi, 25(7), 805-809.

[2]. https://www.vectorstock.com/royalty-free-vector/textile-industrial-isometric-flowchart-vector-22030141. Last Access: 29.05.2023

[3]. Chen, X., Memon, H. A., Wang, Y., Marriam, I., & Tebyetekerwa, M. (2021). Circular Economy and sustainability of the clothing and textile Industry. Materials Circular Economy, 3, 1-9.

[4]. FIDAN, F. S.; AYDOGAN, E. K.; UZAL, NIGMET. An integrated life cycle assessment approach for denim fabric production using recycled cotton fibers and combined heat and power plant. Journal of Cleaner Production, 2021, 287: 125439.

[5]. Dikbas, F., & Mezarcioz, S. (2019). Tekstilde Yasam Dongusu Analizi. Cukurova Universitesi Fen ve Muhendislik Bilimleri, (38), 107-113.

[6]. Baydar, G., Ciliz, N., & Mammadov, A. (2015). Life cycle assessment of cotton textile products in Turkey. Resources, Conservation and Recycling, 104, 213-223.

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Low-Cost Particulate Matter Monitoring Device

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Abstract

Particulate matters are major health-affecting air pollutant and the particulate matter $PM_{2.5}$ is the most hazardous air pollutant among the other air pollutants. PM 2.5 can penetrate into the interior area of the lungs and can cause chronic bronchitis, lung cancer, heart disease, etc. As per World Air Quality Report 2022, the citizens of only 13 out of the 131 countries and regions breathe air containing PM 2.5 within the limit prescribed by the World Health Organisation. As per the guidelines of WHO, the annual concentration level of PM 2.5 should be within the limit of 5µg/m^3. The initial task for the measurement of PM 2.5 is to separate the samples of PM 2.5 from the ambient air. The PM 2.5 samples can be separated using the technique of Cyclone Separators where ambient air enters into a vertical cylinder through a tangential inlet and the generated centrifugal force throws the PM 2.5 samples to the wall of the cylinder. In an Impactor technique, PM 2.5 samples can be separated by collision against a flat surface. For the measurement of the mass of the collected PM 2.5 samples, the useful methods are Taper Element Oscillating Microbalance (TEOM), Beta Ray Attenuation, Gravimetric Method, etc. These conventional PM 2.5 measuring systems are large in size, heavy and costly. In this research work, the scattering property of light has been used where light is forced to deviate from a straight path due to collision with the particulate matter. When the scattered light is projected to the window of a photodetector then according to the intensity of the scattered light, the output voltage of the photodetector varies and the concentration of the particulate matter $PM_{2.5}$ present in the ambient air is determined. This PM 2.5 measuring device is small in size and low-cost device.

Keywords: Air pollution, photodetector, $PM_{2.5}$, scattering of light

1. INTRODUCTION

There are various types of pollutants in the atmosphere. Among these pollutants, particulate matter is severely detrimental to our health. Fine particulate matter $PM_{2.5}$ is the most harmful to our health than the particulate matter PM_{10} and can penetrate more deeply into the lungs [1]. Particulate matter is formed due to soil erosion, building construction, smoke from fires, fly ash, etc.

As per WHO Air Quality guidelines [Global Update 2005] for particulate matter, ozone, nitrogen dioxide, and sulphur dioxide, the acceptable limit of particulate matter $PM_{2.5}$ should be

10 µg / m^3 .... [annual mean] and

25 µg / m^3 .... [24-hour mean] [2]

According to Global Update 2005, WHO considered four common air pollutants; particulate matter (PM), ozone(O_3), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2).

There are various organizations related to environmental conservation like **Environmental Protection Agency (EPA) in the** United States [3], **European Environment Agency (EEA) in the** European Union, etc. [4].

As per WHO global air quality guidelines 2021, recommended Air Quality Global (AQG) levels for particulate matter $PM_{2.5}$ is

$5\ \mu g / m^3$ .... [annual mean] and

$15\ \ g / m^3$ .... [24-hour mean] [5]

The value of particulate matter varies to some extent with atmospheric conditions like temperature, relative humidity, wind speed, geographic location (coastal and non-coastal parts), etc. In the coastal environment, particulate matter is enriched with sodium nitrate and sodium chlorides.

Particulate matter is suspended in the ambient air when its masses are low and sizes are small. Various methods can be used to detect particulate matter. The Environmental Protection Agency (EPA) of the USA and the European Environment Agency (EEA) of the European Union specified design standards for the measurement of particulate matter [6]. Scientists and researchers are investigating various new cost-effective methods for the measurement of specific-size particulate matter using the scattering property of light in the range of infrared rays, LASER beams, and light of visible range [7].

The measurement technique of particulate matter is mainly based on the selection of the size of the particulate matter and the mass of particulate matter. Size selection involves the diameter of the particulate matter in µm and the quantity is measured [8]. The concentration of mass is measured in µg per unit volume (m^3).

In the conventional method, initially PM 2.5 samples are collected from the ambient air using Cyclone Separator, Impactor Technique, and other methods [9]. For measuring the collected particulate matter, the methods like Tapered Element Oscillating microbalance (TEOM), Beta Ray Attenuation, Gravimetric Method, etc. are used [10].

2. CONVENTIONAL METHOD OF MEASUREMENT

2.1 *Cyclonic Separator*

In the Cyclonic Separator, ambient air enters into a vertical cylinder through a tangential inlet and generated centrifugal force throws the PM 2,5 samples to the wall of the cylinder. From the bottom of the cylinder PM 2,5 samples are collected for the purpose of measurement [11].

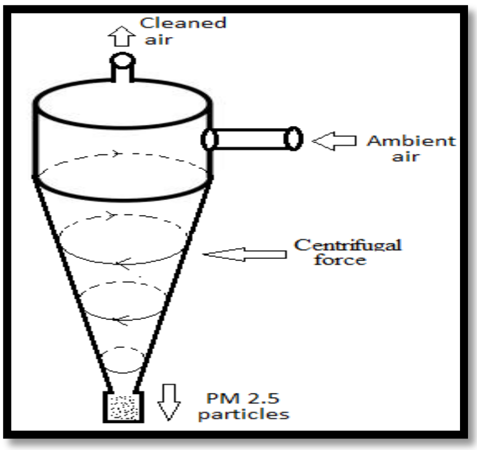


Figure 1. A simple diagram of a Cyclonic Separator

2.2 Impactor Method

In the Impactor method, various separation layers are used. Each separation layer contains porous beds of specific sizes to separate out particles by size. The upper layer has larger holes and particles of smaller diameter pass through the separation layers of larger holes. Gradually particles of smaller diameter are deposited to the corresponding bottom layers according to the size of the particles[12].

2.3 TEOM System

A flow splitter is used to separate the particles of diameter 10 µm and 2 µm. The total flow is separated into two parts. The main flow containing the particles of diameter 2.5 µm enters the sensor unit at a rate of 3 liters/minute and the other flow containing the particles of diameter 10 µm is bypassed through the system [13].

In the TEOM system, mass detection uses a tapered element which is a hollow tube and behaves like a cantilever beam. When a dust particle is deposited onto the cantilever beam then according to the mass of the dust particle, stress is generated onto the free end of the cantilever beam. The wider end of the tapered element is clamped and the other end is free to vibrate or oscillate. [14].

The frequency of oscillation of the free end of the cantilever beam depends upon the physical property of the tapered beam and the mass of particulate matter. A quartz-based crystal oscillator is used and depending upon the mass of the particulate matter the frequency of the oscillator changes. The difference between the natural frequency and the mass effected frequency can be measured by an electronic counter and accordingly, the concentration of particulate matter PM 2.5 can be determined. The drawback of this system is that the filter on which particulate matter is deposited to be changed periodically.

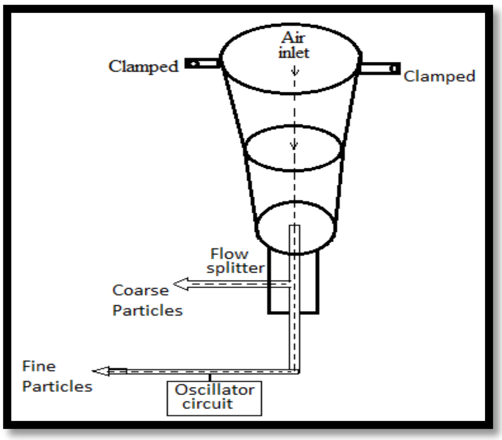


Figure 2. A Simple diagram of a TEOM system

2.4 Gravimetric Method

The Gravimetric sampling system draws sample air at a particular rate onto a filter paper. The PM 2.5 samples are deposited onto the filter paper. The mass of PM 2.5 is measured with the help of a measuring balance. The mass is measured before collecting the samples and after collecting the samples onto a filter paper using a measuring balance [15][16].

3. Scattering Property of Light

Scattering of light is a phenomenon where the light of a particular wavelength is forced to deviate from a straight path due to collision with the particulate matter [17]. The scattering of light is related to the wavelength of the incident light, the diameter of the particulate matter, and the angle between the incident light and the scattered light [18][19][20].

There are three types of scattering of light. When the particle size is less than the wavelength of the incident light, the scattering is called Rayleigh Scattering. The probability of Rayleigh Scattering is $P = 1/\lambda^4$.

When the particle size is equal to the wavelength of the incident light, the scattering is called Mie Scattering and

when the particle size is larger than the wavelength of the incident light, the scattering is called Geometric Scattering.

When the scattered light of selective wavelength is projected to the window of a photodetector then according to the intensity of the scattered light, the output voltage of the photodetector varies.

3.1 Measurement Of Pm 2.5 Using Scattering Of Light

For the measurement of particulate matter PM 2.5 using the scattering property of light, atmospheric air passes through a hole into the scattering chamber. The light is scattered in various directions according to the concentration of the airborne particles and the wavelength of the incident light. For the measurement of particulate matter generally, infrared light-emitting diodes are used as light emitters and the photodiode or phototransistor is used as photo sensors. Two plano-convex lenses are generally used; one is used to make the beam of light parallel which is emitted from the infrared LED so that the maximum number of collisions occurs with the dust particles. Another plano-convex lens is used to make the scattered beam of light into a narrow beam of light so that the maximum number of photons falls on the window of the photodetector. The output of the photodetector determines the concentration of the particulate matter.

The preferred angle between the incident light and the scattered light is generally maintained at a 90-degree angle to avoid the reaching of stray light to the photodetector. Smaller angles are also used so that unwanted light does not reach the window of the photodetector.

3.2 *Block Diagram and Description*

The invisible emitted light from the infrared LED will have a specific wavelength according to the nature of the LED. The emitted light goes through the plano-convex lens and becomes parallel. This light is scattered due to the collision with the incoming dust particles and when this scattered light goes through the other plano convex lens, this scattered light becomes a narrow beam of light. This narrow beam of light will fall into the window of the photodiode. According to the concentration of the dust particles, the output of the photodiode will vary and the output as shown in figure x will also vary.

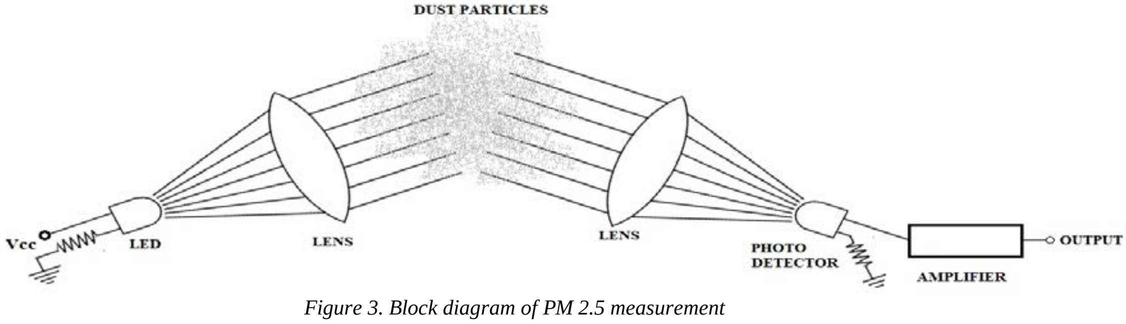


Figure 3. Block diagram of PM 2.5 measurement

4. EXPERIMENTAL SETUP

The experimental setup consists of an electronic circuit, two plano-convex lenses, an infrared LED for emitting infra rays and a photodiode for detecting the emitted infra rays, Arduino UNO R3 microcontroller board for processing the output signal of the photodiode, and a 16 x 2 lines LCD display for displaying the output.

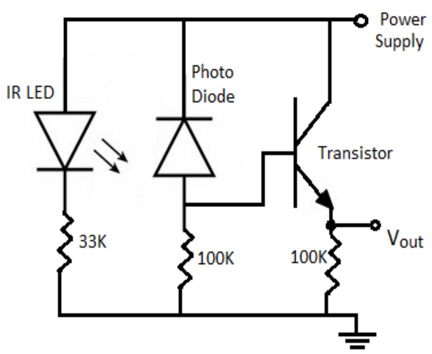


Figure 4(a). Diagram of the amplifier circuit

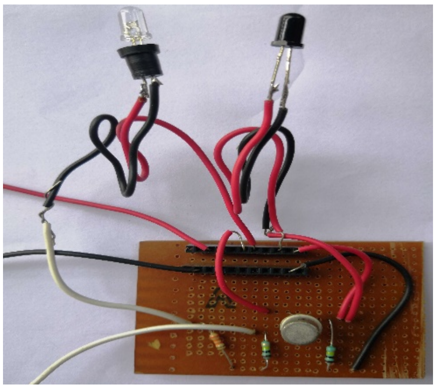


Figure 4(b). Image of the amplifier circuit

The electronic circuit is used for the amplification of output voltage obtained from the photodiode. The output voltage level of the photodiode is low and amplification of the output voltage of the photodiode is required for the purpose of processing. An NPN transistor CL100 has been used as an emitter follower for the amplification of the output voltage obtained from the photodiode [21].

4.1. Plano Convex Lens

Two plano-convex lenses with a diameter 11 mm and 21 mm focal length have been used. One plano-convex lens is used to make the emitted light from the infrared LED parallel for the purpose of maximum scattering when collided with the incoming dust particles into the scattering chamber. The plane side of this lens is positioned towards the light-emitting side of the infrared LED. The other plano-convex lens is used to make the scattered light concentrated for the purpose of maximum detection by the photodiode. The spherical side of this second plano-convex lens is positioned towards the incoming scattered rays and the plane side is positioned towards the photodiode.

4.2 Infrared LED and Photodiode:

In a LED, due to the application of the forward bias, electrons and holes are recombined to emit light. The electrons from n-side are injected into the p-side and the holes from p-side are injected into the n-side. The emission of light is created by the injected carriers and in a LED light is emitted spontaneously [22]. In this experiment, the infrared LED emits maximum light at a 940 nm peak wavelength. The photodiode used in this experiment also detects light of a peak wavelength of about 940 nm. The photodiode is used in reverse biased [23]. The output voltage of the photodiode varies as per the intensity of emitted rays from the infrared LED and it falls into the window of the photodiode.

4.3 Arduino UNO R3 Microcontroller Board:

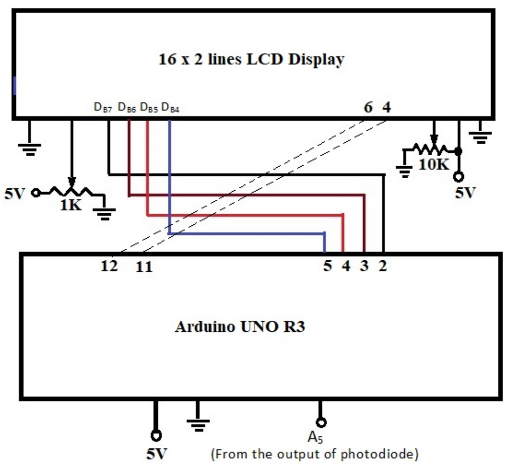
The Arduino UNO R3 board uses an ATmega328 AVR microcontroller [24]. ATmega328 AVR is an 8-bit microcontroller [25]. There are options to apply 5 Volt and 3.3 Volt supply to the Arduino Board and there is also a regulated power supply to apply an external variable power supply up to 12 volts generally. As an external power supply, a 9-volt battery is frequently used. The drop-out current will be more when external supply voltage will be large. Arduino UNO R3 can deliver 40 – 50 mA currents.

Arduino UNO R3 has six analog input pins and 14 digital I/O pins. The analog input pins are A_0 to A_5. The analog input pins take analog voltages generally from the sensors and by using built-in 10-bit ADC, it converts the analog voltages to any value between 0 to 1023 according to voltage levels applied to the analog input pins. For this conversion, the function **analogRead(n)** is used [26]. In this experiment, analog input pin A_5 has been used. The amplified output voltage obtained from the amplifier circuit is connected to the A_5 pin of Arduino. The output from the Arduino can be displayed in an LCD display module. The output value can also be displayed on the PC by setting the COM Port values of the Arduino Board using Serial Monitor setting options and following the COM Port values of Device Manager.

4.4. LCD Display

In this experiment, one 16 x 2 lines LCD display has been used for the display of the result. Data lines DB_4, DB_5, DB_6, and DB_7 have been used [27]. To adjust the contrast of the display a variable 5V supply has been connected to the V_{EE} pin of the LCD display. The RS pin (command register/data register) of the LCD display has been connected to pin No. 12 of the Arduino UNO R3 Board. The Enable pin (No. 6) of the LCD display has been connected to pin No.11 of the LCD display to latch the information given to its data pins. A 5V DC supply has been applied to the V_{DD} pin (No. 2) of the display for its working. We can display the data at any location of 16 columns and 2 rows using the command **lcd.setCursor(column,row).**

The value can also be displayed on the computer monitor screen using the serial monitor as shown in Figure 9. The particulate matter is measured by counting the number of particles per cubic meter of volume or by their masses/weights.



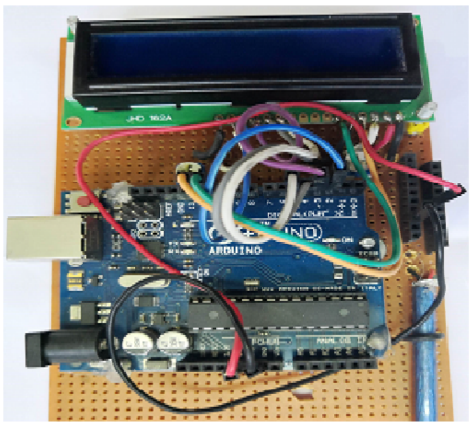


Figure (6a). Diagram of Arduino with LCD

Figure (6b). Practical diagram Arduino with LCD

In Figure 7, the image of the plano-convex lenses and their fittings in the paper tube including the scattering chamber has been shown. The scattering chamber has been made black to prevent the reaching of stray lights on the window of the photodiode.

Figure 7. *Image of (a) Plano-convex lens (b) Lenses fitted in the paper tube (c) Lenses encapsulated in a scattering box*

Figure 8 shows the value of particulate matter PM 2.5 on the LCD display.

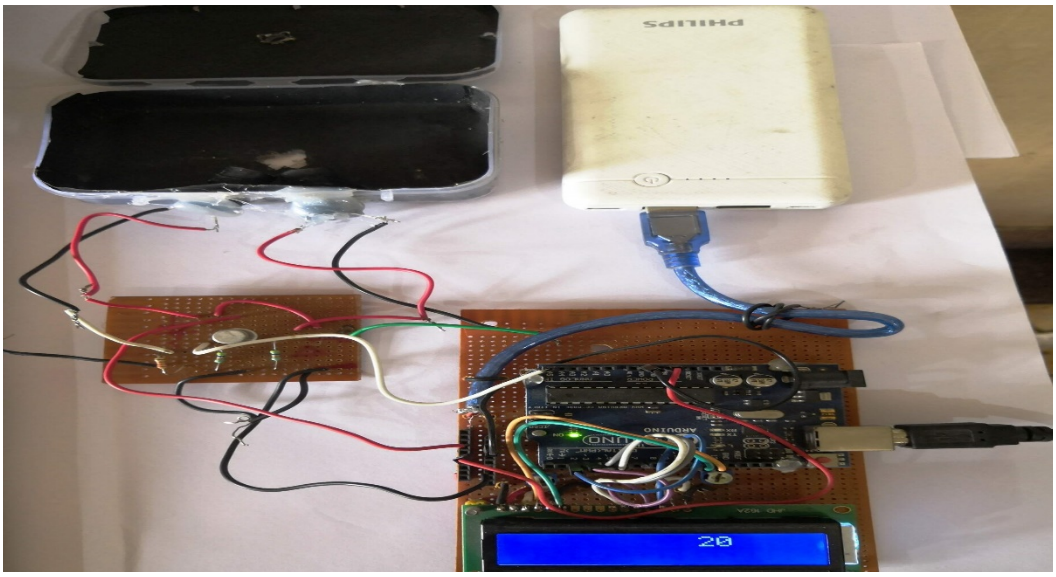


Figure 8. Displays the value of PM 2.5 in μg/m^3

Figure 9 shows the value PM 2.5 on the display as well as on the PC. Both the values on the display and on the PC are the same.

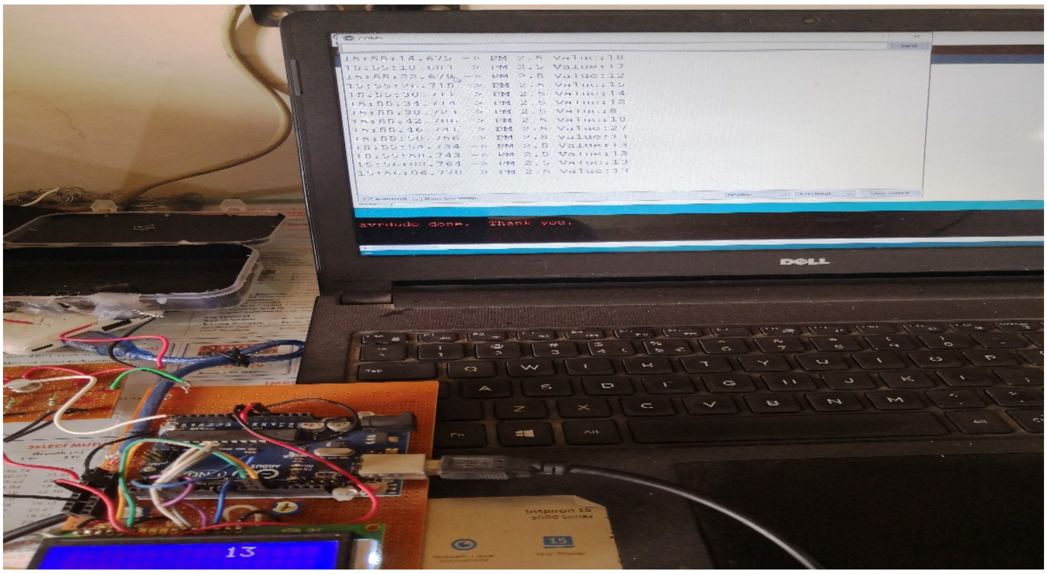


Figure 9. A practical image with the connection of Arduino with LCD, Electronic Circuit and Lenses encapsulated in a black box and Serial Monitor.

CONCLUSIONS

The apparatus used for the measurement of particulate matter PM 2.5 in the conventional method is very large and costly. The measurement method using the property of scattering of light is small in size and low-cost device. But the lenses are to be oriented carefully and precisely in this method. The wavelength selection of the infrared LED and the wavelength detection capacity of the photodiode is also important. The scrubber is to be periodically changed for getting good results. The calibration is to be done also against a standard PM 2.5 measurement device.

REFERENCES

[1] Y. F. Xing, Y. H. Xu, M. H. Shi, and Y. X. Lian, “The impact of PM 2.5 on the human respiratory system,” Journal of the Thoracic Disease, vol. 8(1), pp. 1-9, Jan. 2016.

[2] https://www.who.int/publications/i/item/WHO-SDE-PHE-OEH-06.02

[3] https://www.epa.gov/regulatory-information-topic/regulatory-and-guidance-information-topic-air

[4] https://www.eea.europa.eu/en/newsroom/news/air-pollution-levels-across-europe

[5] https://www.who.int/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution

[6] X. Li, B. Ruan, P. K. Hopke, and T. Mehmood, “On the performance parameters of PM 2.5 and PM_1 size separators for ambient aerosol monitoring,” Aerosol and Air Quality Research, vol. 19, pp. 2173-2184, 2019.

[7] G. Chen, J. Guang, Y. Xue, Y. Li, Y. Che, and S. Gong, “A physically based $PM_{2.5}$ estimation model using AERONET data in Beijing area,” IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. II. No. 6, pp. 1957- 1965, June 2018.

[8] D. A. Vallero, Fundamentals of Air Pollution, 4th edition, USA, Academic Press (Elsevier Inc.), 2008.

[9] Qin et al., “Micro quartz tuning fork-based $PM_{2.5}$ sensor for personal exposure monitoring”, IEEE Sensors Journal, vol. 19, April 2019.

[10] C. N. Hewitt and A. V. Jackson, Handbook of Atmospheric Science: Principles and Applications, 1st ed., USA, Blackwell Publishing, 2003.

[11] L. Wang, C. B. Parnell, B.W. Shaw, and R. E. Lacey, “A theoretical approach for predicting number of turns and cyclone pressure drop,” Transactions of the ASABE, vol. 49(2), pp. 491-503, 2006.

[12] J. R. Mudakavi, Principles and Practices of Air Pollution Control and Analysis, 1st ed., New Delhi, India, I.K. International Pvt. Ltd., 2020.

[13] A.E. Ray and D.L. Vaughn, “Standard Operating Procedure for the Continuous Measurement of Particulate Matter”. https://www.epa.gov/sites/default/files/2021-03/documents/905505_teom_sop_draft_final_sept09.pdf

[14] G. Allen, C. Sioutas, P. Koutrakis, R. Reiss, F.W. Lurmann and P. T. Roberts, “ Evaluation of the TEOM® method for measurement of ambient particulate mass in urban areas,” Journal of the Air & Waste Management Association, vol. 47, pp. 682-689, Jun. 1997.

[15] Y. ZHU, T. J. SMITH, M. E. DAVIS, J. LEVY, R. HERRICK, AND H. JIANG, “COMPARING GRAVIMETRIC AND REAL-TIME SAMPLING OF PM 2.5 CONCENTRATIONS INSIDE TRUCK CABINS,” JOURNAL OF OCCUPATIONAL AND ENVIRONMENTAL HYGIENE, VOL. 8(11), PP. 662-672, NOV. 2011.

[16] Y. WANG, W. YANG, B. HAN, W. ZHANG, M. CHEN, AND Z. BAI, “GRAVIMETRIC ANALYSIS FOR $PM_{2.5}$ MASS CONCENTRATION BASED ON YEAR-ROUND MONITORING AT AN URBAN SITE IN BEIJING,” JOURNAL OF ENVIRONMENTAL SCIENCES, VOL. 40, PP. 154-160, FEB. 2016.

[17] J. Fraden, Handbook of Modern Sensors: Physics, Designs, and Applications, 4th ed., New York, USA, Springer, 2010.

[18] A. R. Jones, “Light scattering for particle characterization,” Progress in Energy and Combustion Science, vol. 25, pp. 1-53, Feb. 1999.

[19] W. Shao, H. Zhang, and H. Zhou, “Fine particle sensor based on multi-angle light scattering and data fusion,” Sensors, vol. 17, pp. 1-15, May 2017.

[20] P. L. Magill, F.R. Holden and C. Ackley, Air Pollution Handbook, New York, USA, McGraw-Hill Book Company, 1956.

[21] A. P. Malvino, Electronic Principles, 3rd ed., New Delhi, Tata McGraw-Hill Publishing Company Ltd., 1984.

[22] P. Swaminathan, Semiconductor materials, devices, and fabrication, 1st ed., New Delhi, India, Wiley, 2019.

[23] S. O. Kasap, Principles of electronic materials and devices, 3rd ed., New Delhi, India McGraw Hill Education, 2007.

[24] E. Williums, Make: AVR Programming, 1st ed., Mumbai, Shroff Publishers & Distributors Pvt. Ltd.,2014.

[25] [www.microchip.com].

[26] [www.arduino.cc].

[27] M. A. Mazidi, J. G. Mazidi, and R. D. McKinlay, The 8051 Microcontroller and Embedded Systems Using Assembly and C, 2nd ed., New Delhi, India, Pearson Education, Inc., 2006

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Importance of Water Supply System for Public Health

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Abstract

It is well known that polluted water is dangerous to health. Pollution of fresh water ecosystems is often the cause of diseases, and therefore a multidisciplinary approach involving hydrology, engineering, urban planning and public health is necessary for a good public health outcome. It has been recognized that a water supply system is connected with the improvement of public health of the population. Can diseases such as diarrhea in isolated rural areas or malaria in Africa be prevented through good water supply management? There is an opinion that water supply management is also public health management and that it is a very good tool in reducing and controlling diseases and will definitely play a big role in the future. Protected drinking water is essential for public health. The most common microorganisms associated with waterborne diseases are: Campylobacter, Legionella, Cryptosporidium, Norovirus, E. coli and Giardia. Legionella has been proven to be one of the most important causes of diseases associated with the water supply systems. Investing in water infrastructure is therefore investing in the safety of drinking water, which is the basis of public health, and its pollution can even lead to a potential epidemic caused by various microorganisms. The paper will present the most common diseases that can potentially be transmitted through the public water supply system, as well as the differences in the infrastructure in different parts of the world, which play a major role in public health of the population. The importance of a good water supply system and the environment in preventing diseases that are potentially spread by contaminated drinking water will be shown. Also, possible dangers of contamination of drinking water that the population uses on a daily basis will be pointed out.

Keywords: polluted water, public health, water supply system, waterborne diseases

1. INTRODUCTION

We collect water for water supply from natural sources; we use it, and return wastewater back to nature. The characteristic feature of today's world is that the heavily polluted wastewater is increasing and the quality water supply is decreasing. In addition to high water pollution levels, losses occurring in the water supply system have a major impact on water supply. Such lost water does not reach the end consumers and is not even charged by the water supply company. All of this is due to the "water crisis", which means that a large part of the population on Earth has no access to drinking water or the basic hygienic living conditions [1].

One of the preconditions for a healthy life of people is access to drinking water through public water supply services and the drainage of contaminated wastewater through public drainage services. UN General Assembly Resolution 64/292 of 2010 affirmed the right to safe and clean drinking water and wastewater drainage as a human right essential for the full enjoyment of life and all human rights [2], [3], [4].

Since the creation of the human community there has been a need to provide conditions for supply of drinking water as well as for other human activities. At the same time, the question of disposal of used wastewater was also raised. These issues have been addressed by civilizations, from ancient times to present, and will continue to be addressed in the future, because these are issues without which there is no normal life on planet Earth [5]. Water is considered to be one of the basic components of life, and the entire history of mankind and civilization is largely related to it. Water is not only included in the composition of human organism and food, but it is also used to produce food and energy, and it is used in industry as a raw or auxiliary material. Due to its importance

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for humans, the supply of water to settlements and the population is nowadays considered to be one of the primary branches of water management. In the tendencies of concentration of settlements and consumers around water, and given the available water resources on Earth, the issue of water supply will become ever stricter in the future. The rule of water supply that every drop of water on the catchment is kept as long as possible for its wider use, is becoming more and more present in our practice. All the aforesaid affect the emergence of complex water supply and drainage systems [6].

It has already been noted that the investment in sanitary infrastructure and in its development has a significant impact on the reduction of population mortality [7], [8], [9], as authors [8], [9] researched and established in their papers. The area they studied and analysed was England, Wales, Switzerland, Finland and Sweden. The authors of the study [8] deal with the issues and research of the impact of the improvement of sanitary infrastructure on mortality in urban environments. Their special focus was to study the improvement of water supply and the development of efficient sewer systems. These improvements are likely to have the greatest health impact by reducing exposure to diseases transmitted by water and food [8]. Various studies have confirmed that good sanitation in a city has the major impact on public health [10]. The biggest reduction in mortality from waterborne infectious diseases was due to the establishment of improved sanitary conditions [11].

The paper [12] analyses the impact of works on water supply networks and sewer systems in German cities in the period from 1877 to 1913. The results of the research presented in the paper show that safe drinking water reduces mortality, but more importantly investment in sanitary infrastructure that contributes to the reduction of mortality. They also found that the limited impact of only safe-distribution of drinking water through water network on mortality reduction was limited. Greater influence is achieved by combining the construction of water and sewer systems - networks. The results of the author's second paper [13] support other studies that highlighted the role of public health infrastructure, although it has been shown that the provision of clean drinking water alone has limited effects. In the absence of effective methods for the removal of urban waste, decontamination of water and disease vectors, they neutralise some of the benefits of water from the water supply (i.e. the construction of the water supply network) [13].

2. WATER SUPPLY SYSTEM

The practice of transporting water for human consumption has been around for several millennia. From the first pipes in Crete some 3500 years ago, to today's complex hydraulic models, the history of water distribution technology is quite a story [14].

Water supply and sewer system are the most important services and integral part of urban society and infrastructure. Water infrastructure cannot function well and efficiently without other urban infrastructure, in particular transport and electricity supply. Construction, operation and maintenance of urban infrastructure are a permanent and expensive process. Today, the management of urban water systems faces many problems such as:

1) The need for reliable sources of drinking water.
2) Significant flood damage as a result of the urbanisation of the catchment area and the possession of water inundation.
3) Deterioration of water quality, pollution and depletion of groundwater, and negative impact on residents including the coastal sea into which water is discharged from urban water systems.
4) Health problem caused by pollution of water resources and seas [15].

The most common and user-friendly access to water for human consumption and sanitation is ensured through public water supply and sanitation systems operated by public water service suppliers [16]. Water supply services are provided by means of a water supply system, and drainage services are provided by means of a public drainage system, i.e. a sewer system. Water supply system is a collection of buildings and devices for the supply and distribution of water from the site to the consumer. It covers all necessary system facilities: source, main supply pipeline, water improvement facilities, water supply, main supply pipeline and distribution network.

Fundamentally, a water supply system may be described as consisting of three basic components: the source of supply, the processing or treatment of the water, and the distribution of water to the users [17]. Typical elements of the water supply management system are presented in Table 1.

Table 8. Typical elements of the water supply management system (according to [18])

Component	Subcomponents
Water source	Lakes/Rivers
	Reservoir
	Ground water
Treatment plant	Filtration
	Coagulation
	Disinfection
Transmission and distribution	Pipe networks
	Service reservoirs
	Storage tanks
End users	Potable water

The basic roles of the water supply system, regardless of all possible variants and specificities, are:

- Ensuring quality water treatment from the environment to drinking water, the quality of which must comply with legal requirements, both in the processing phase and up to the consumption phase;
- Continuity in water supply 24 hours 365 days a year, all consumers;
- Necessary, sufficient amounts of water for all consumers in the defined area of the system [5].

Ensuring a sufficient quantity of quality water is primarily of great health importance in protecting against various diseases transmitted by water. Sufficient amounts of water in settlements make it possible to increase the general standard of living of man and to regulate his environment. Large quantities of water are needed to satisfy the growing needs of populated places. Water distributed to the public must have a drinking water standard in accordance with the law [15].

In 2020, an estimated 90% of the world population had access to at least basic drinking water services. Access was highest in Europe and North America and Australia and New Zealand, with 100% of both regions having access to at least basic drinking water services. In most regions of the world, 90% of the population has access to at least basic drinking water services. However, just 65% of the population in Sub-Saharan Africa and 57% of the population in Oceania had basic access in 2020 [19]. Estimated share of global population with access to at least basic drinking water services in 2020, by Sustainable Development Goal (SDG) region [19] is shown in the Figure 1.

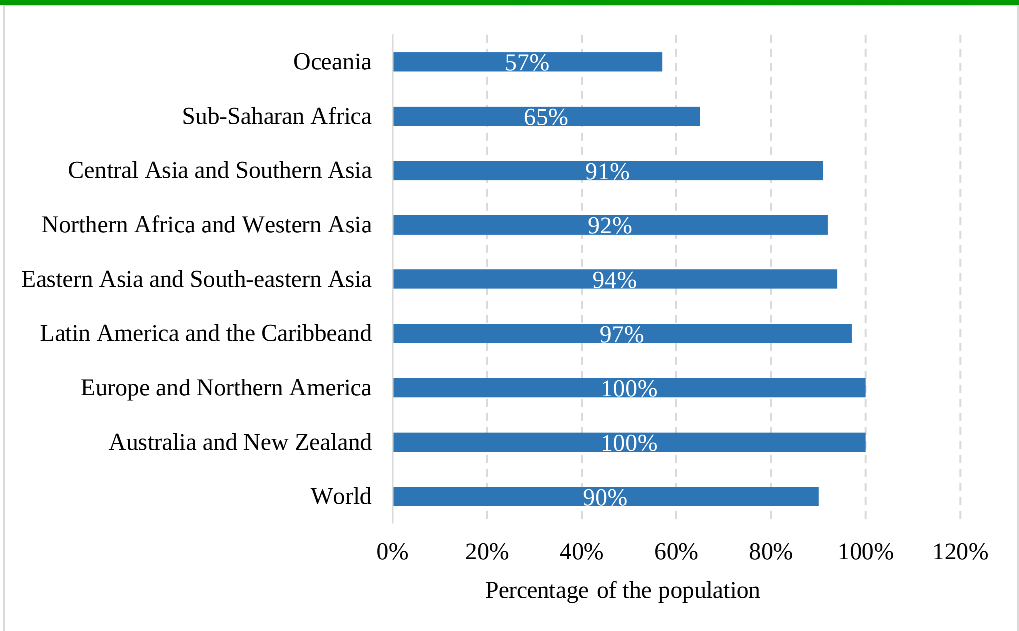

Figure 1. Estimated share of global population with access to at least basic drinking water services in 2020, by SDG region [20]

There are differences in distribution of drinking water in the world. Figure 2 shows the number of people across the world that do not have access to safe drinking water. Safely managed drinking water is defined as an “improved source located on premises, available when needed, and free from microbiological and priority chemical contamination” [21].

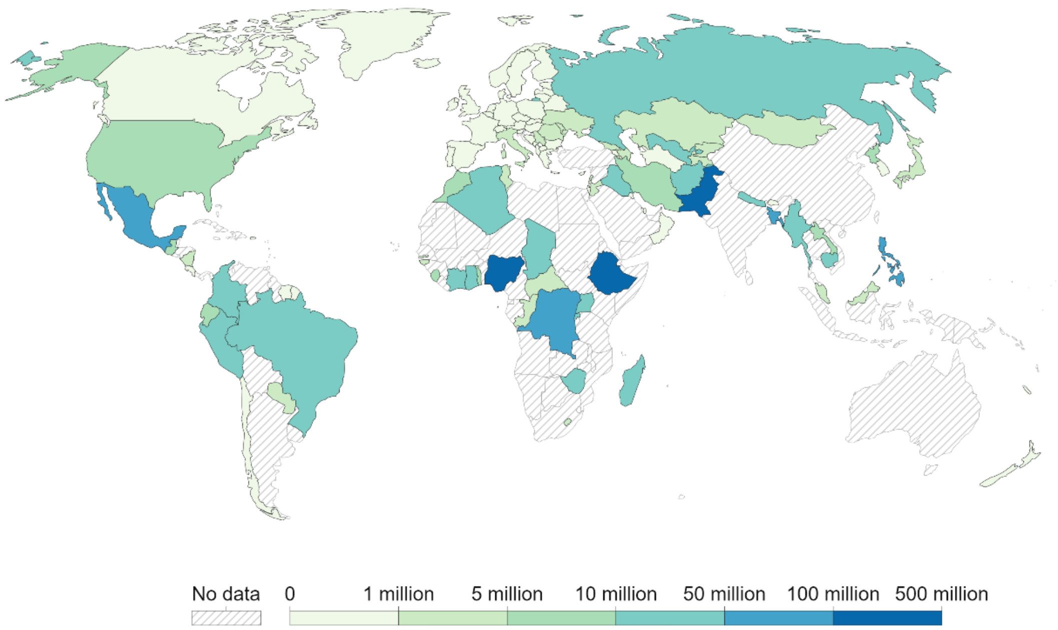

Figure 2. Number of people without access to safe drinking water, 2020 [21], [22]

3. WATERBORNE DISEASES

Clean water is the key factor for public health. Waterborne diseases are one of the most important diseases known as typhoid fever, rotavirus diarrhea, or pandemic cholera disease. Each of the listed in history was one of the most important causes of death at the time. In 2006, the WHO showed that contaminated water and lack of basic sanitation led to at least 1.6 million deaths in children under 5 years of age in 2004 [23].

The causes of these diseases are different. And they are called pathogenic organisms. They include viruses, bacteria and protozoa [24]. The pathogen is every microorganism that causes the disease. Water contaminated by microorganisms may cause a disease either directly (e.g. drinking such water) or indirectly (consumption of vegetables washed in contaminated water). Most pathogens causing waterborne diseases are primarily transmitted by faecal contamination. Thus, monitoring faecal pollution by bacteria in water is a necessary and relatively cheaper way of protecting the public health of the population from faecal - transmissible pathogens. Unfortunately, studies in the 1970s have shown that faecal indicators are not always affected by the concentration of pathogens. The scenario that occurred in Ontario is a good example, where the presence of *E. coli* did not mean the presence of the pathogenic *E. coli* O157:H7 [25].

The link between the disease and microorganisms was established back in the time of Robert Koch in the 1880s. In 1854, John Snow (Figure 3), the father of epidemiology, linked exposure to contaminated drinking water to cholera transmission, when an English water company supplied residents of London with contaminated drinking water [25], [26]. Insecure water supply, ineffective sanitation, and hygiene can be one of the major causes of diarrhea and the leading cause of death of about 1.58 million people each year. [25], [27].

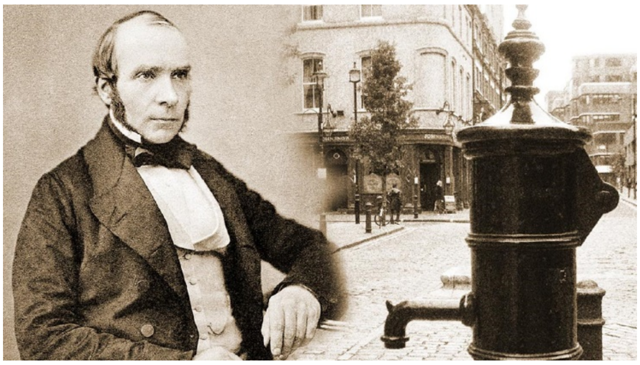

Figure 3. John Snow [28]

Table 2 shows the most common pathogens of waterborne diseases by category and name of microorganisms.

Table 2. Agents of Waterborne or Water-based Disease [24]

Category	**Pathogens**
Bacteria	*Vibrio cholerae*
	Salmonella spp.
	Shigella spp
	Campylobacter spp.
	Yersinia enterocolitica
	Legionella
	Helicobacter pylori
	Toxigenic *Escherichia coli*
Protozoa	*Giardia lamblia*

	Cryptosporidium parvum
	Entamoeba histolitica
	Isospora belli
	Toxoplasma gondii
	Naegleria fowleri
	Microsporidia
	Ballantidium coli
Viruses	Norovirus
	Sapprovirus
	Poliovirus
	Coxsackievirus
	Enteroviruses 69-91
	Adenovirus
	Hepatitis A
	Reovirus
	Rotavirus
	Coronavirus

Legionella is one of the most common causes of waterborne diseases. *Legionella* is the major cause of waterborne illness outbreaks in the USA [29], [30], [31]. Large *Legionella* outbreaks receive the most attention given their substantial health impact. However, it is estimated that less than 20% of all reported legionellosis cases are outbreak-related [30], [32], [33]. Worldwide, waterborne *Legionella pneumophila* is the most common cause of cases including outbreaks. *Legionella pneumophila* and related species are commonly found in lakes, rivers, creeks, hot springs and other bodies of water [34].

In Canada, reported rates of legionellosis in 2006–2020 (the latest year for which data have been published) were 0.37–1.75 per 100,000 population [30], [35]. Reported rates from the USA were 1.0–1.89 per 100,000 population in 2006-2016 [36], [37]. As legionellosis is underdiagnosed and underreported, the actual number of cases is expected to be much higher [38].

4. WATERBORNE DISEASES IN THE WORLD

Water pollution is a global problem, according to the World Health Organization (WHO), 2.1 million people do not have access to safe drinking water sources [39]. The WHO said the minimum water requirement per person for one day is about 7.5 to 10 litres [23].

As access to quantities of water increases, the public health risks decrease (see Table 3) [23], [40], [41]. When water is scarce, then people are forced to drink unsafe water, and water cannot be easily spared for hygiene or sanitation.

Table 3. World Health Organization summary of water access, adequacy and level of health concern [23], [40], [41]

Service level	Access measure	Needs met	Health concern
No access <5L/c/day	>1 km; 30 minutes	Consumption not assured; hygiene not possible	Very high
Basic-often<20 L/c/day	100-1000 meters; 5-20 min	Consumption should be assured; hand washing and basic food hygiene; laundry/ bathing no	High
Intermediate~50 L/c/day	Within 100 m, 5 minutes, or by single tap	Consumption, ditto basic personal and food hygiene, laundry/bathing	Low
Optimal >100L/c/day	Supplied by multiple taps	Consumption and hygiene-all needs met	Very low

L/c/day – liters per capita per day

By comparison, in wealthy countries, residents use 200-300 litres per day for drinking, sanitation, cooking, hygiene, not to mention the unnecessary and uncontrolled use of drinking water to wash cars or clean (watering) the garden or watering grass surfaces [23].

Diarrhea, which is closely associated with contaminated drinking water, coupled with poor sanitation, causes many cases of disease. Diarrheal disease is very high, accounting for 1.7 to 5 billion cases per year worldwide. Specifically, diarrheal diseases are associated with an estimated 1.3 million deaths annually, with most occurring in resource-limited countries. Very young children are the most vulnerable, the incidence of severe gastroenteritis being highest in the first 2 years of life. Indeed, up to 25% of deaths in young children in Africa and south-east Asia are attributable to acute gastroenteritis [42], [43]. Waterborne diseases can range from light, self-limiting diseases to serious diseases such as typhoid fever and cholera. Serious cases end in death unless treated.

In Sub-Saharan Africa significant progress has been made in reducing the risk for children under the age of five, but progress is slower for newborns. The region accounts for 38% of global neonatal deaths and has the highest infant mortality rate (34 deaths per 1,000 live births in 2011). There are many causes of such a high mortality rate, but poor hygiene during childbirth could account for up to 15% of neonatal deaths [44], [45]. Lack of access to water and sanitation is linked to neonatal infection and maternal mortality. It is estimated that clean childbirth practices could avert 6 to 9% of the 1.16 million annual newborn deaths in countries in Sub-Saharan Africa [44], [46].

Many women giving home birth do not have access to clean water and sanitation (less than 10% according to a study examining data from 22 Western and Central African countries) [44], [47]. Even women who attend a health care facility may not be guaranteed acceptable hygiene standards. A WHO survey of health care facilities in a selection of low- and middle-income African states revealed that 42% did not have an improved water source within 500 metres of the facility, 16% did not have improved sanitary facilities and more than 45% lacked adequate handwashing facilities [48].

Diarrhea is particularly dangerous for children and it is the fourth cause of death of children under the age of 5 in poorly developed parts of the world. Effective treatment of drinking water, however, can kill or inactivate the more than 20 waterborne pathogens. Several of these pathogens are already antibiotic resistant and have taken first place on the WHO global pathogen list. So, clean safe water is the first line of defence against serious diseases that will soon become incurable due to antibiotic resistance. Safe water is also needed to prevent diseases that can arise from inhaling contaminated water droplets, or aerosols, associated with air conditioning systems, spas and devices or systems that produce mists or sprays. These include outbreaks caused by the bacteria Legionella, which can be the most significant waterborne pathogen in high-income countries. Safe and sufficient drinking water is also key to maintaining the health of people who are vulnerable to opportunistic infections (e.g., people living with HIV/AIDS) [49]. It is also estimated that 1.8 million people globally are at risk of potential COVID-19 infection through faecal contamination of drinking water [50]. Death rates are much higher in low-income countries [21]. Figure 4 shows estimated annual number of deaths attributed to unsafe water sources per 100,000 people.

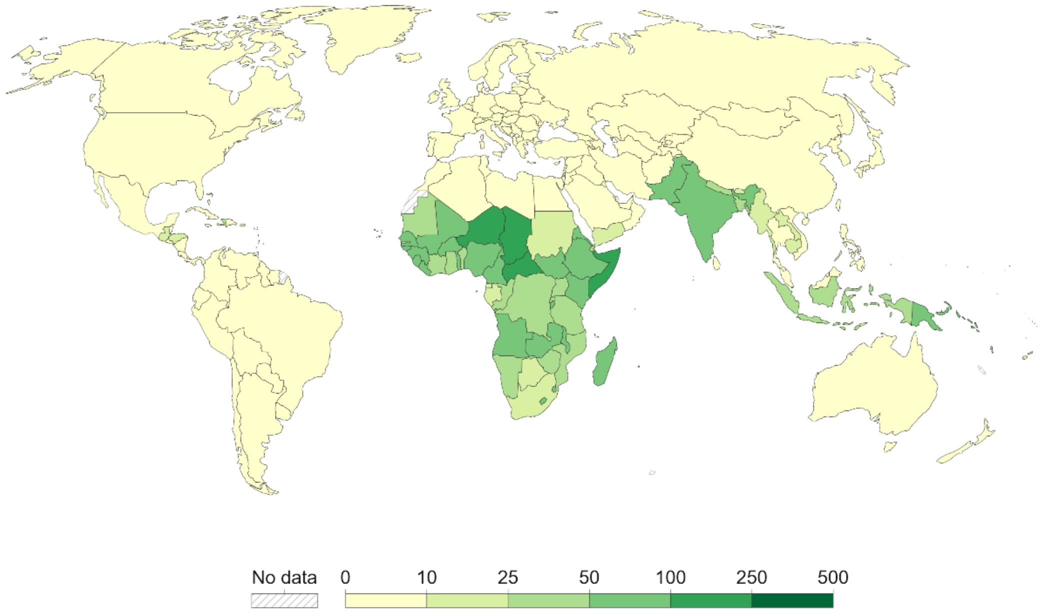

Figure 4. Death rate from unsafe water sources, 2019 [21], [51]

Figure 4 shows large differences in death rates between countries: rates are high in lower-income countries, particularly across Sub-Saharan Africa and Asia. Rates here are often greater than 50 deaths per 100,000 – in the Central African Republic and Chad this was over 100 per 100,000 [21].

CONCLUSIONS

Water is essential for people's life and health. Proper sanitation, including proper wastewater management, is essential to ensure human health, a healthy ecosystem, and economic and environmental benefits. Due to its importance for people, the supply of water to settlements and the population is nowadays considered one of the primary branches of water management. Water is distributed to end consumers through the water supply system. The most important roles of the water supply system are ensuring quality water processing from the environment to drinking water, the quality of which must comply with legal regulations, continuous water supply 24 hours a day for all 365 days of the year and sufficient quantities of water for all consumers on the system space. Sufficient quantities of quality and proper drinking water in settlements provide a prerequisite for the protection of the health of residents. This prevents people from becoming infected with diseases transmitted by water. There is a different availability of drinking water in the world. Thus, in 2020, it is estimated that 90% of the world's population had access to at least basic drinking water services. The biggest access was in Europe, North America, Australia and New Zealand. However, in sub-Saharan Africa only 65% of the population have access and 57% of the population in Oceania. Without water, there is no life, and the health of the body depends largely on the state of the water we bring into it. In case of water contamination from water supply, the intake of such contaminated water into the body can cause disease for a large number of people and animals and can thus lead to a pandemic in a very short period of time. The intake of contaminated water can infect us with various diseases such as: dysentery, typhoid belly, cholera, rotavirus diarrhea, infectious hepatitis, etc. Some of the most common causes of waterborne diseases are bacteria, protozoa, and viruses. Diarrhea, which is closely associated with contaminated drinking water, coupled with poor sanitation, causes many cases of disease. By ensuring sufficient quantities of quality drinking water, it is possible to prevent different diseases transmitted by water, maintain proper health - hygiene conditions and reduce the risk of death associated with inadequate hygiene conditions (due to insufficient quantities of water and its poor quality). Water is the most important and the most used natural resource on Earth, so its health is essential, as well as proper and careful water management.

REFERENCES

[1]. M. Šperac and D. Obradović, “Water Supply and Sewerage System in the Republic of Croatia and the Republic of Slovenia”, in Proc. ICOEST 2020, Sarajevo, pp. 25-33.

[2]. V. Trbojević, Zaštita potrošača korisnika vodne usluge opskrbe vodom, Republika Hrvatska, Ministarstvo zaštite okoliša i energetike, Uprava vodnoga gospodarstva i zaštite mora, 4. Ciklus edukacija namijenjenih udrugama za zaštitu potrošača, Zagreb, 19. listopada 2018.

[3]. United Nations, General Assembly: Resolution adopted by the General Assembly on 28 July 2010, A/RES/64/292, 3 August 2010.

[4]. D. Obradović, M. Šperac and S. Marenjak, “Challenges in Sewer System Maintenance”, *Encyclopedia*, vol. 3, pp. 122-142, 2023.

[5]. P. Uskoković, *Osnovne karakteristike sistema za snabdevanje vodom i odvođenje otpadnih voda bitnih za razmatranje njihovog održavanja*, in: Udruženje za tehnologiju vode i sanitarno inženjerstvo, Beograd, Savremena eksploatacija i održavanje objekata i opreme vodovoda i kanalizacije, pp. 79-84, 2010.

[6]. S. Milenković, *Vodovod i kanalizacija zgrada*, treće dopunjeno izdanje, AGM knjiga, Beograd, 2007.

[7]. K. Kosić, (Ed.), *Kanalizacija 1892. - 1992.* Zagreb: Javno poduzeće “Kanalizacija” Zagreb, Zagreb, 1992.

[8]. B. Harris and J. Helgertz, “Urban sanitation and the decline of mortality”, *The History of the Family*, vol. 24, no. 2, pp. 207–226, 2019.

[9]. A. Hinde and B. Harris, “Mortality decline by cause in urban and rural England and Wales, 1851–1910”, *The History of the Family*, vol. 24, no. 2, pp. 377–403, 2019.

[10]. R. Dillingham and R. L. Guerrant, “Childhood stunting: measuring and stemming the staggering costs of inadequate water and sanitation”, *Lancet*, vol. 363, no. 9403, pp. 94–95, 2004.

[11]. L. Cain and E. Rotella, “Death and spending: urban mortality and municipal expenditure on sanitation”, *Annales de Démographie Historique*, vol. 1, no. 101, pp. 139–154, 2001.

[12]. D. Gallardo Albarrán, “Sanitary infrastructures and the decline of mortality in Germany, 1877-1913.”, *GGDC Research Memoranda*, vol. 176. Groningen: GGDC., 2018.

[13]. D. Gallardo-Albarran, “Sanitary infrastructures and the decline of mortality in Germany, 1877–1913”, *The Economic History Review*, vol. 0, no. 0, pp. 1-28., 2020.

[14]. M. Haestad, M. T. Walski, D. V. Chase, D. A. Savic, W. Grayman, S. Beckwith and A. Koelle, *Advanced Water Distribution Modeling and Management*, First edition, Haestad Press, Waterbury, CT USA, 2003., p. 10

[15]. J. Margeta, *Vodoopskrba naselja (autorizirana skripta)*, Sveučilište u Splitu, Građevinsko-arhitektonski fakultet, Sveučilište u Zagrebu, Geotehnički fakultet, Varaždin, Split, Varaždin, 2009.

[16]. Vlada Republike Hrvatske: Prijedlog odluke o pristupanju promjeni Ustava Republike Hrvatske, s prijedlogom …, Klasa: 022-03/19-12/40, Urbroj: 50301-25/05-19-6, 29. kolovoza 2019., Zagreb

[17]. National Research Council (US) Safe Drinking Water Committee. Drinking Water and Health: Volume 4, Washington (DC): National Academies Press (US), 1982.

[18]. B. Kazeem Adedeji, H. Yskandar, “Cyber-Physical Systems for Water Supply Network Management: Basics, Challenges, and Roadmap”, *Sustainability*, vol. 12, 9555, 2020.

[19]. Share of population with access to basic drinking water 2020, by region, Statista, 2023, [Online]. Available: https://www.statista.com/statistics/267480/population-with-access-to-advanced-drinking-water-sources-by-world-regions/ (Accessed: 05.05.2023.)

[20]. Estimated share of global population with access to at least basic drinking water services in 2020, by SDG region, Statista, [Online]. Available: https://www.statista.com/statistics/267480/population-with-access-to-advanced-drinking-water-sources-by-world-regions/ (Accessed: 05.05.2023.)

[21]. H. Ritchie and M. Roser (2021) "Clean Water and Sanitation". Published online at OurWorldInData.org. [Online]. Available: https://ourworldindata.org/clean-water-sanitation (Accessed: 05.05.2023.)

[22]. Share of the population with access to safely managed drinking water, 2020, Our World in Data, [Online]. Available: https://ourworldindata.org/grapher/number-without-safe-drinking-water (Accessed: 05.05.2023.)

[23]. J. K. Griffiths. *Waterborne diseases*. Elsevier, pp. 551-563, 2008.

[24]. K. Reynolds, K. Mena and C. Gerba, “Risk of waterborne illness via drinking water in the United States”, *Reviews of Environmental Contamination and Toxicology*, vol. 192, pp. 117-158., 2008.

[25]. R. Bared, K. H. Bartlett, W. Bowie, “Dealing with waterborn disease in Canada: Challenges in the Delivery of safe drinking water”. *Reviews on environmental health*, pp. 119-123, 2008.

[26]. R. R. Frerichs, “History, maps and the Internet: UCLA's John Snow site”, *Society of Cartographers Bulletin*, vol. 34, no. 2, pp. 3-7, 2000.

[27]. World Health Organization. Water, sanitation and hygiene links to health: Fact and Figures 2004, 4 January 2007. [Online]. Available: http://www.who.int/water_sanitation_health/publications/facts2004/en/index.html (Accessed: 13.05.2023.)

[28]. Artis Micropia, John Snow, [Online]. Available: https://www.micropia.nl/en/discover/microbiology/john-snow/ (Accessed: 12.05.2023.)

[29]. K. Neil and R. Berkelman, “Increasing incidence of legionellosis in the United States, 1990–2005: Changing epidemiologic trends”. *Clinical Infectious Diseases*, vol. 47, no. 5, pp. 591–599, 2008.

[30]. Guidance on waterborn pathogens in drinking water. Health Canada, 2022, pp. 29-34.

[31]. K. M. Benedict, H. Reses, M. Vigar et al., CDC, Surveillance for waterborne disease outbreaks associated with drinking water-United States, 2013–2014. MMWR., vol. 66, no. 44, pp. 1216–1221., 2017.

[32]. B. S. Fields, R. F. Benson and R. E. Besser, “Legionella and Legionnaires’ disease: 25 years of investigation”, *Clinical Microbiology Reviews*, vol. 15, no. 3, pp. 506–526., 2002.
[33]. A. Burillo, M. L. Pedro-Botet and E. Bouza, “Microbiology and epidemiology of Legionnaires’ disease. Infectious Disease Clinics of North America, vol. 31, no. 1, pp. 7–27, 2017.
[34]. WHO, Legionellosis, 2022. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/legionellosis (Accessed: 18.05.2023.)
[35]. Government of Canada, PHAC, Notifiable diseases on-line. Reported cases from 1924 to 2020 in Canada, Public Health Agency of Canada, Ottawa, Canada, 2023. [Online]. Available: https://diseases.canada.ca/ndis/charts?c=pl (Accessed: 19.05.2023.).
[36]. D. A. Adams, K. R. Thomas, R. A. Jajosky, L. Foster, P. Sharp et al. “Summary of notifiable infectious diseases and conditions—United States, 2014”, *MMWR Morbidity and Mortality Weekly Report*, vol. 63, no. 54, pp. 1–152, 2016.
[37]. D. A. Adams, K. R. Thomas, R. A. Jajosky, L. Foster, G. Baroi, P. Sharp, D. H. Onweh, A. W. Schley and W. J. Anderson, “Summary of notifiable infectious diseases and conditions—United States, 2015”, *MMWR Morbidity and Mortality Weekly Report*, vol. 64, no. 53, pp. 1–143, 2017.
[38]. N. E. Castillo, A. Rajasekaran and S. K. Ali, “Legionnaires’ disease: A review”, *Infectious Diseases in Clinical Practice*, vol. 24, no. 5, pp. 248–253, 2016.
[39]. M. L. Zlati, L. P. Georgescu, C. Iticescu, R. V. Ionescu and V. M. Antohi, “New Approach to Modelling the Impact of Heavy Metals on the European Union’s Water Resources”, *International Journal of Environmental Research and Public Health*, vol. 20, paper 45, 2023.
[40]. G. Howard, J. Bartram and World Health Organization (WHO), *Domestic Water Quantity, Service, Level and Health*, WHO Press, 2003. Switzerland
[41]. G. Howard, J. Bartram, A. Williams, A. Overbo, D. Fuente and Jo-A. Geere, *Domestic water quantity, service level and health*, Second edition, World Health Organization 2020.
[42]. D. Amicizia, R. T. Micale, B. M. Pennati, F. Zangrillo, M. Iovine, E. Lecini, F. Marchini, P. L. Lai, and D. Panatto, “Burden of typhoid fever and cholera: similarities and differences. Prevention strategies for European travelers to endemic/epidemic areas”, *Journal of Preventive Medicine and Hygiene*, vol. 60, no. 4, pp. E271–E285. 2019.
[43]. GBD Diarrhoeal Diseases Collaborators, “Estimates of global, regional, and national morbidity, mortality, and aetiologies of diarrhoeal diseases: a systematic analysis for the Global Burden of Disease Study 2015”, *The Lancet Infectious Diseases*, vol. 17, no. 9, pp. 909-948., 2017.
[44]. African Development Bank, United Nations Environment Programme, GRID-Arendal, *Sanitation and Wastewater Atlas of Africa*, 2020.
[45]. United Nations Children’s Fund (UNICEF), Levels and trends in child mortality: Report 2017. Estimates Developed for Child Mortality Estimation, 2017. [Online]. Available: https://www.unicef. org/publications/index_101071.html. (Accessed: 10.05.2023.)
[46]. J. Lawn and K. Kerber, The Partnership for Maternal, Newborn and Child Health, *Opportunities for Africa’s Newborns: Practical data policy and programmatic support for newborn care in Africa*, Geneva, WHO on behalf of Partnership for Maternal, Newborn and Child Health, 2006.
[47]. G. Gon, M. C. Restrepo-Méndez, O. M. Campbell, A. J. Barros, S. Wood, L. Benova et al., “Who delivers without water? A multi country analysis of water and sanitation in the childbirth environment”, *PloS ONE*, vol. 11, no. 8, 2016.
[48]. United Nations Children’s Fund and World Health Organization, Progress on Sanitation and Drinking Water: 2015 Update and MDG Assessment, Geneva, 2015.
[49]. WHO, UNICEF, World Bank. State of the world’s drinking water: an urgent call to action to accelerate progress on ensuring safe drinking water for all. Geneva: World Health Organization, 2022.
[50]. A. Olatunbosun Sojobi and T, Zayed, “Impact of sewer overflow on public health: A comprehensive scientometric analysis and systematic review”, *Environmental Research*, vol. 203, 2022.
[51]. Our World in Data, Death rate from unsafe water sources, 2019, Our World in Data, [Online]. Available: https://ourworldindata.org/grapher/death-rates-unsafe-water (Accessed: 13.05.2023.)

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The Degradability And Toxicity Analysis Of Mc-Rr As a Cyanobacterial Toxin By Ultrasonic Oxidation

Zeynep Eren[1] , Meliksah Tekin[2]

Abstract

In this study, the degradation of MC-RR which is one of the most important cyanobacterial toxin compounds detected in surface waters in recent years, by ultrasonic oxidation, as an advanced oxidation processes (AOPs) in an ultrasonic reactor including low and high frequencies was investigated. Ultrasonic oxidation of MC-RR was carried out separately for each frequency in an ultrasonic system with both low frequencies (20 kHz and 40 kHz) and high frequencies (578 kHz, 862 kHz, 1142 kHz). According to the literature, MC-RR was analyzed by liquid chromatography-mass spectrometry/mass spectrometry (LC-MS/MS) method, since it is found in ng/L or µg/L levels in surface waters. Since MC-RR is supplied at analytical grade, it was not used any extraction process before chromatography. The toxicity analyzes of by-products of MC-RR were carried also out. The toxicity of MC-RR solutions obtained after ultrasonic oxidation was analyzed via a healthy mouse liver cell line (AML-12). The results obtained from the oxidation of MC-RR in ultrasonic systems in 30 minutes showed that the degradation efficiency was up to 12%. Since the degradability of microcystin group compounds is generally low, it has been seen in the literature that similar groups have low oxidation efficiency. Toxicity analysis with the AML-12 cell line showed that the initial solution of MC-RR had a toxic effect close to 15% on healthy cells; it was observed that the toxicity of the by-products obtained either remained the same or increased to a maximum of 20% at the end of ultrasonic oxidation.

Keywords: Microcystins, Ultrasonic treatment, Algal bloom

1. INTRODUCTION

Phytoplankton are autotrophic organisms that carry out over 95% of the photosynthesis in the oceans and account for half of the net global primary production. For primary production, phytoplankton need a source of carbon from the dissolved CO_2 by transferring from the atmosphere to the water, light and other nutrients such as nitrogen, phosphorus and sulfur in the environment. Cyanobacteria are a globally widespread group of photosynthetic bacteria, also known as blue-green algae, found in all freshwater ecosystems. Eutrophication was first seen in Western Europe and North America lakes and reservoirs in the 1950s, and since then it has become widespread especially in some regions, causing deterioration in the aquatic environment and significant problems especially in drinking water treatment (Figure 1) [1-2].

Increasing surface water temperatures due to the effects of climate change, and nutrient loads accelerate eutrophication and related harmful algal blooms (HAB) in aquatic environments (WHO 1999; Turner et al. 2018). Among the toxins produced by cyanobacteria, the most important species are Microcystis. Microcystis species and other features cause important environmental problems such as eutrophication resulting taste and odor problems in drinking water worldwide [3-4].

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Membrane filtration, especially ultrafiltration can be successful algae removal process, but treatment of dissolved cyanobacterial toxins is not very effective due to the pore size [5]. Activated carbon adsorption has some advantages and disadvantages, they have been frequently used in the effective treatment of MCs in recent years by combining with other treatment methods. AOPs can be used as a pretreatment step to convert resistant organic pollutants into biologically treated structure, or as a post-treatment step before they are discharged into the environment [6-7]. There are limited studies on the ultrasonic oxidation of microcystins in the literature, and most of them are on the oxidation of MC-LR.

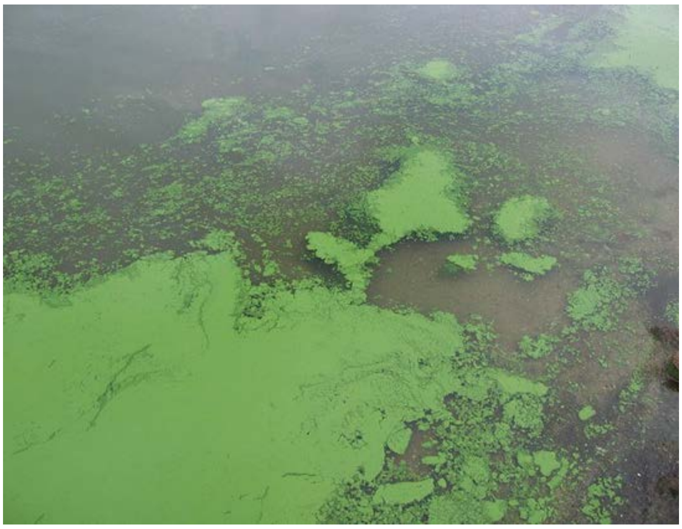

Figure 1. Harmful Algal Bloom Problems in surface water sources [8].

2. MATERIALS AND METHODS

In this study, the oxidation of MC-RR, one of the most important cyanobacterial toxin compounds, which have been detected quite frequently in aquatic environments in recent years, in a 20 and 40 kHz low and 578, 862, 1142 kHz high frequency ultrasonic system in the laboratory and the toxicity of the by-products examined as well. MC-RR concentrations were analyzed with LC-MS/MS (Agilent Technology 6460 Triple Quad LC/MC) and the analyzes were made in Ataturk University Central Laboratories (DAYTAM) with service procurement.

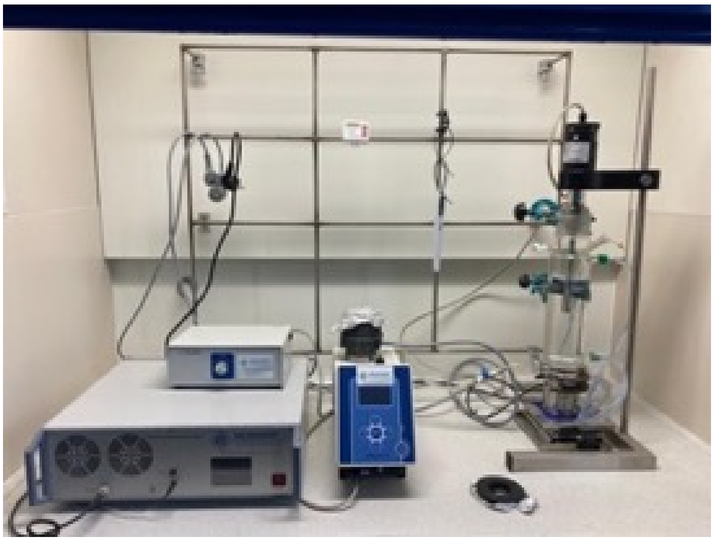

Figure 2. Ultrasonic oxidation equipment.

3. RESULTS AND DISCUSSION

In this study, the degradability and post-treatment toxicities of MC-RR, one of the most important compounds in the cyanobacterial toxin group, were investigated in a low and high frequency ultrasonic system. For this purpose, the ultrasonic system used in the experiments carried out in the laboratory environment is 20 kHz to 40 kHz low; It has high frequencies of 578 kHz, 862 kHz and 1142 kHz. Toxicity tests were performed by in-vitro method using AML-12 healthy mouse liver cells. The initial concentration of MC-RR used in the study was 1.25 µg/L and the initial pH natural value was determined as 6.00±0.2. The initial test volume is 750 mL. Sampling times are 1, 3, 5, 10, 15, 20, 25 and 30 minutes. The decrease (C/Co) in the concentration of MC-RR, which was initially oxidized to 20 kHz ultrasonic oxidation during the 30 min reaction time, is shown in Figure 3.

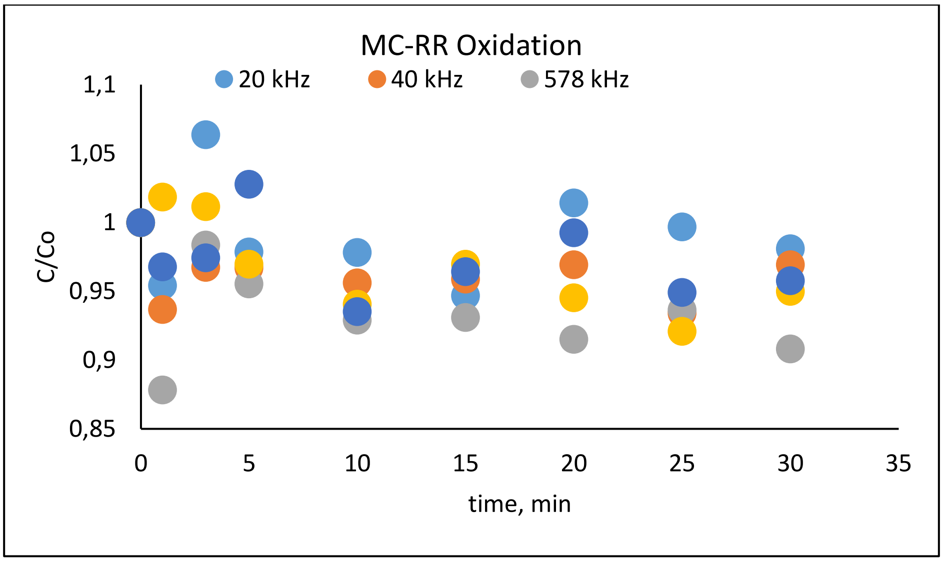

Figure 3. The concentration decrase of MC-RR by ultrasonic oxidation in different frequencies.

The concentration reduction by ultrasonic oxidation in the 20, 40 low and 578, 862 and 1142 kHz high frequency reactor has been shown. It can be seen from this Figure that high frequency ultrasonic oxidation is more effective on the degradation of MC-RR than low frequencies. A degradation efficiency of 10-12% was recorded after 30 minutes of oxidation relative to the initial concentration (Figure 3). We used healty mouse liver cells to test toxicity of MC-RR after ultrasonic oxidation. The toxicity effect of MC-RR at an initial concentration of 1.25 µg/L on AML-12 cell culture was reduced from 100% to 85.6% showing its toxicity (Figure 4).

According to the results obtained from a total of five ultrasonic oxidation systems, it was observed that high frequency systems were more successful in breaking down the MC-RR, but there was a frequency optimum. Increasing MC-RR concentrations in the reaction time seen in low frequency systems were also observed at other high frequencies except for the 578 kHz frequency. From this point of view, the oxidation efficiency of the 578 kHz ultrasonic system in breaking down intermediate products can be mentioned. This effect is described as “cushioning effect” in the literature. As the high power applied to the system at high frequencies will generate more temperature in the reactor, the vapor content of the solution increases, which has a cushioning effect on the collapsing bubble, that is, it increases the resistance against the inward collapse of the cavitation bubble during the collapse phase. This reduces the energy released and then the number of free radicals decreases. This means less oxidation efficiency [9].

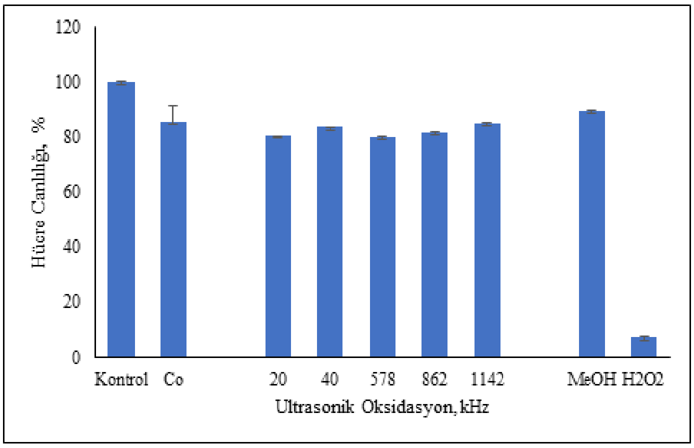

Figure 4. Conference banner

According to Figure 4, the toxicity effect of MC-RR at an initial concentration of 1.25 µg/L on AML-12 cell culture was such that cell viability was reduced from 100% to 85.6%. Initial 1.25 µg/L MC-RR solution at 20 kHz to 40 kHz low for 30 minutes; The toxicity effect of the solutions obtained by subjecting them to ultrasonic oxidation at high frequencies of 578 kHz, 862 kHz and 1142 kHz separately for 30 minutes on the AML-12 cell line remains the same at 1142 kHz oxidation, but decreases slightly in others. Accordingly, it is observed that the oxidation products in all ultrasonic systems do not have a great toxic effect compared to the starting solution. In other words, ultrasonic oxidation products had an increased toxic effect on AML-12 cells at rates varying between 5-6% compared to the initial solution. The toxicity of the products obtained by ultrasonic oxidation of MC-RR for 30 minutes is 1142 kHz, which is the same as the initial MC-RR solution. However, the recovery efficiency is also very low. At the end of the study, it was tried to reveal that the ultrasonic oxidation products did not have a much more toxic effect than the initial solution, with both cell images and cell viability test counts.

CONCLUSION

The ultrasonic oxidation of MC-RR, one of the common cyanotoxin compounds in the aquatic environment, was examined at low and high frequencies and the toxicity of post-oxidation products was also evaluated. At the end of the study, it was determined that the most effective improvement efficiency was achieved by the ultrasonic oxidation of the MC-RR at a frequency of 578 kHz for 30 minutes, resulting in a 12% concentration reduction. Initial concentrations of MC-RR (1.25 µg/L) reduced the viability of healthy mouse liver cells to around 85%; At the end of oxidation in all ultrasonic systems, cell viability either remained the same or increased by 5% compared to the initial concentration. With this aspect, the study is capable of forming a basis for future studies by considering parameters such as ultrasonic oxidation time, initial pH and initial MC-RR concentration.

ACKNOWLEDGMENT

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REFERENCES

[1]. Amé, M. V., Galanti, L. N., Menone, M. L., Gerpe, M. S., Moreno, V. J., & Wunderlin, D. A. (2010). Microcystin–LR,–RR,–YR and–LA in water samples and fishes from a shallow lake in Argentina. Harmful Algae, 9(1), 66-73.
[2]. Anderson, D. M., Glibert, P. M., & Burkholder, J. M. (2002). Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. Estuaries, 25, 704-726.
[3]. Chorus, I., Bartram, J. 1999. "Toxic Cyanobacteria in Water", Chapter 10, Editorler: Bartram, J., & Rees, G. Monitoring bathing waters: a practical guide to the design and implementation of assessments and monitoring programmes. CRC Press.

[4]. Codd, G. A., Metcalf, J. S., & Beattie, K. A. 1999. "Retention of Microcystis aeruginosa and microcystin by salad lettuce (Lactuca sativa) after spray irrigation with water containing cyanobacteria", Toxicon, 37(8), 1181-1185.
[5]. Antoniou, M. G., De La Cruz, A. A., Pelaez, M. A., Han, C., He, X., Dionysiou, D. D., ... & Sharma, V. K. 2014. "Practices that prevent the formation of cyanobacterial blooms in water resources and remove cyanotoxins during physical treatment of drinking water", Elsevier Inc..
[6]. Eren, Z. (2012). Ultrasound as a basic and auxiliary process for dye remediation: a review. Journal of Environmental Management, 104, 127-141.
[7]. Eren, Z., & O'Shea, K. (2019). Hydroxyl radical generation and partitioning in degradation of methylene blue and DEET by dual-frequency ultrasonic irradiation. Journal of Environmental Engineering, 145(10), 04019070.
[8]. USEPA 2022a. Indicators: Cyanobacteria, https://www.epa.gov, Access Date: 29.01.2023.
[9]. de Andrade, F. V., Augusti, R., & de Lima, G. M. (2021). Ultrasound for the remediation of contaminated waters with persistent organic pollutants: A short review. Ultrasonics Sonochemistry, 78, 105719.

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Analysis of Bioclimatic Features of Vernacular Architecture – A Case Study of Vernacular Residential Buildings in Sarajevo

Sandra Martinović[1], Nurin Zečević[2], Azrudin Husika[3]

Abstract

The imperative of today's architects and urban planners is to identify and implement sustainable solutions that would increase the overall quality of the urban environment and people's well-being, by maintaining a natural balance and integrity. In this regard, the bioclimatic principles of vernacular architecture can serve as inspiration for designing buildings in a contemporary urban context. This approach can help to gain knowledge about the practices of vernacular architecture, and define solutions that can deal with today's urban challenges, such as urban and environmental pollution, lack of comfort, and low quality of life. This paper presents the analysis of bioclimatic features of three well-preserved vernacular residential buildings, located in Sarajevo, Bosnia and Herzegovina. The research methodology is based on the literature research, photo documentation, and field observation, regarding the presence of bioclimatic design principles, such as building form, orientation, layout, use of local building materials, topography, traditional passive strategies - sun shading, cooling and natural-induced ventilation, natural landscape, and comfortable living environment. The results of this research showed that the selected vernacular buildings fulfill most of the basic bioclimatic principles, which could be transposed into contemporary architecture, not in the context of a pure replication of an old style, but as a modern sustainable architectural design. The analysis also showed that the potentials of passive heating were not exploited in the best possible way, therefore the improvement of the building design will be a necessary step in order to be implemented in the design of sustainable architecture.

Keywords: Contemporary architecture, Sustainability, Vernacular architecture, Bioclimatic features.

1. INTRODUCTION

In recent decades, a dynamic trend of urban expansion has been noticeable, accompanied by population growth, modifications in the spatial and social forms of cities, and economic prosperity [1], [2]. Urban settlements, which are often viewed as a "complex phenomenon" [3, p.6], contributed to the transformation of the lifestyle and the environment itself, through significant impact on socialization, improvement of living standards, and economic development [4]. Considering that every progress also has its negative impact, the current global situation is the indicator that the outcome of such progress significantly leads to an "environmentally, socially and economically unsustainable" direction [1, p.8].

A significant increase in concerns about environmental conditions, climate change, and energy crises, has "forced" society to reconsider the mistaken belief that nature is only there to satisfy the needs of humanity, providing unlimited availability of natural resources [4], [5]. This situation required the transformation of environmental consciousness, as well as strategies and activities in the context of sustainability, with the aim of reestablishing a balance between man-nature-architecture, and "the need to protect the environment in order

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to preserve human welfare“ [4], [5, p. 41]. These sustainable principles are not a new paradigm, as mentioned in the [5, p.35] “the history of architecture tells us that architecture has been sustainable since its birth and that since its very origin, it has satisfied many of the needs that today are no longer met.” The origins of today’s sustainable architectural principles can be found in the design principles of indigenous architecture, known as vernacular architecture. The tendency of vernacular builders was to design and construct buildings in a way that minimizes their environmental impact and maximizes their social and economic benefits [6]. Design solutions relied on passive bioclimatic strategies that incorporated architecture and the natural environment, through the use of local materials, natural resources, traditional construction techniques, site features (climate, morphology, orientation), building design (layout, form), and passive strategies (cooling, ventilation, solar, water, and vegetation) [5], [7], [8]. Traditional building, in accordance with these principles, "is integrated into the environment and does not harm other elements of the ecosystem" [5, p. 44], providing residents with a healthy and comfortable living environment. Many researchers believe that the benefits of this type of architecture can be used for future sustainable building design, due to its design strategies that use bioclimatic-passive principles in the architectural context [9], [10]. But it is necessary to take care that the implementation of sustainable principles of vernacular architecture should not be a mere imitation of the concept in the contemporary design because otherwise, it will represent a risk of “ignoring the lessons of sustainability of local vernacular architecture, without taking into account specific local conditions and materials, based on other vernacular architectures from faraway lands, in other environments and with other basic conditions” [5, p. 36].

In this paper, we will analyze the presence of bioclimatic features in three representative and well-preserved vernacular residential buildings from the Ottoman period, located in Sarajevo, the capital of Bosnia and Herzegovina (B&H). The chosen houses are significant as a cultural heritage and national monuments. The focus of research will be on the analysis of the environmental-social sustainability features – appropriate topography, orientation, and location on the site; building compactness; use of locally available materials and resources; use of non-polluting materials; adequate strategies for passive cooling and natural ventilation; adequate natural lighting and sunshine protection; vegetation and greenery; healthy and comfortable microclimate. The aim is to estimate if such building design can serve as a role model for the integration of traditional and modern design values, with a tendency to achieve modern sustainable buildings, with optimal energy consumption and environmental performance, and enhanced thermal and visual comfort.

2. CONCEPT OF TRADITIONAL URBAN SETTLEMENTS IN SARAJEVO

Bosnia and Herzegovina is one of the countries characterized by its rich architectural heritage. Its architecture was mainly created under the influence of the political and social changes of the different development periods, and each period had an authentic impact on the development of cultural diversity and specific architectural expression [11]. The period that had a strong influence on Bosnian architecture, especially through the emphasized relationship of architecture to nature and life, was the Ottoman period. In that period, along with the development of urban planning, urban areas began to emerge and acquire their basic form, the organization which is still noticeable today [11].

Architecture, as well as urbanism, was organized around a series of unwritten laws, which included: human proportions, unobstructed views, geometry, open and flexible spaces, simple furniture, spatial connections with nature, and the use of local and traditional construction methods [11]. Although it seems that the architecture of B&H had the characteristics of Ottoman-oriental architecture, it also had some of its specific characteristics, when domestic builders, neimars, introduced elements of the local traditions.

Mahalla was one of the traditional settlements that was significant due to its conceptualization as a residential area of the city, located outside the main traffic arteries. The residential house adapted to the environment by using natural, local materials for construction, respecting climate, and fitting in the terrain due to the exceptional skills of domestic builders. In Sarajevo, houses in mahallas, as peri-urban residential settlements, were placed on the hillside, gradually, with a carefully chosen building site in accordance with the non-written, building law – to respect the right of view and the right to privacy, Figure 1 [12].

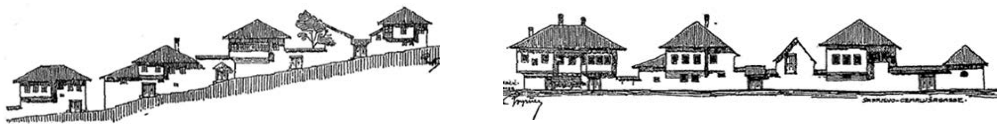


Figure 1. Horizontal and vertical displacement of houses – “the right of a view” [12]

Mahallas were connected by alleys or sokaks that were branching off on both sides of the main street, where were entrances to the houses. From the street, the houses blended into the ambiance and formed an integral part of the mahalla, and the houses can be considered as belonging to anyone and for anyone as long as they are all in human proportions [13]. For the visitors, the house is hidden and protected from the outside views by a high white wall, as a physical boundary between built and unbuilt environment, with a characteristic courtyard door, as a very significant element of housing in functional and decorative terms [13], [14].

As much as the residential complex is separated from the outside world, from the street and the uninvited curiosity of passengers, the house and its layout were so open towards nature, as an integral part of every house in the mahalla. Gardens or avlija provided comfortable and healthy microclimate for living, a source of joy, and the entire complex in the architectural sense represents a harmonious relationship, where nature becomes an element of the composition and nature passes into architecture [13], [15], [16]. There was a strong emphasis on vegetation, and gardens were decorated with a variety of fruit trees, and flowers [12], [13]. The natural environment, according to an unwritten rule, was also enriched by flowing, clean water. The presence of water was important because of two reasons: one is the sanitary needs, to which a lot of attention was paid, and the other is the desire to enjoy the freshness and the noise of that water [12], [17].

The construction of the house was quite simple, characterized by cubic forms, gently sloping roofs, different floor materialization, verandas, courtyards, and doksat on the first floor, overhanging the street. The combination of closed, open, and semi-open spaces, was primarily due to the desire for space, and the desire for nature to be part of the architectural composition, creating a high degree of unity. Houses were built mostly from natural materials, such as stone, wood, and adobe brick [12], [17], [18]. The domestic architecture used mainly adobe bricks because it required less effort and expense for the production, processing, and transportation than stone, which was done near the construction site. Wood retains its natural appearance and structure everywhere, as a constructive element and an architectural decoration [12]. The common use of this construction material was due to the forest wealth of B&H.

3. RESEARCH METHODOLOGY

The aim of this research is to analyze the bioclimatic features of vernacular residential architecture on the example of three well-preserved vernacular town houses, located in Sarajevo, B&H, and to examine if the good architectural principles and practices of vernacular architecture can serve as an inspiration for the design of sustainable contemporary buildings. The performed analysis consists of literature study, photo documentation and field observation. Based on the collected data and layout drawings obtained from the study literature and observation on the site location, a detailed survey was conducted regarding the presence of bioclimatic design principles. The analysis of the various bioclimatic elements of the chosen vernacular houses includes the investigation of the following characteristics:

- Building location and utilization. When planning the integration of bioclimatic elements into the building, it is very important to take into account microclimatic factors, such as climate and landscape, with the aim to find the right location with lots of sun, wind, vegetation, and water in order to create a healthy living microclimate. The influence of these factors is reflected through proper orientation, positioning, form, and materialization of the building [19, p.19]. These natural elements can also be used for passive heating and cooling [7]. Building utilization refers to optimizing the size of the spaces inside the house, without disturbing their comfort, in order to reduce heating and cooling demands.

- Building form and orientation. Considering the orientation of the building in the process of planning and construction of the building, it can have a significant impact on “the energy performance of the building throughout its life cycle” [19, p.18]. That is why the integration of proper design (form, orientation, spatial configuration) and natural resources of the environment [5], [19], can enable diverse solutions that contribute to energy consumption reduction and internal comfort. The openings have to be positioned in a way to make maximum use of daylight and reduce the need for artificial lighting. During the winter it is important to use as much solar heat gains as possible to reduce energy demand for heating.

- Local, natural building materials and construction. The focus should be on using materials that have environmental advantages, such as natural, locally found materials with low environmental impact; recyclable or biodegradable, and with good thermal characteristics [5], [19]. Building construction has to be adapted to the local climate conditions.

- Natural cooling and ventilation. Natural ventilation can be obtained through proper orientation of the building, facade openings (size, disposition, quantity) and sun shading elements that do not obstruct free airflow. Natural vegetation (gardens, courtyards) and the presence of water (water fountains), can be used as additional elements of passive cooling.

4. CASE STUDY – ANALYSIS OF THE BIOCLIMATIC FEATURES OF VERNACULAR RESIDENTIAL BUILDINGS IN SARAJEVO

In this paper, three vernacular houses in Sarajevo from the Ottoman period are analyzed: Alija Đerzelez's house (Figure 2), Sabura's house (Figure 3), and Svrzo's housing complex (Figure 4). Chosen houses were built during the 17th Century and represent the most authentic examples of residential architecture from that period in B&H, which survived in their original form or have been restored, partially or completely to this day. The Commission to Preserve National Monuments designated these houses as national monuments of Bosnia and Herzegovina.

The locations of the buildings were carefully chosen. Houses were built on slopes of the hills, positioned towards the most beautiful views of the city, in a way not to obstruct neighbors' views. These locations are airy with plenty of sunshine. The position of the houses in accordance with the terrain confirms that „buildings exist within an environmental context“ [5, p. 43], meaning that achieved livability and building characteristics were influenced by „site's feature, culture and local climate“ [5, p.43].

Figure 2. Alija Đerzelez's house [20]

Figure 3. Sabura's house [21]

Figure 4. Svrzo's house (Source: Authors, 2022.)

Organizationally, each house was divided into four functional units: habitation, leisure and relaxation, utility, and outer spaces with vegetation and water. Conceptually, this included: the fence, which defined the street and separated the private from the public space; the courtyard, which was cobbled; the fountain as a basic part of hygiene before entering the house; the garden; the ground floor, or semi-private space where the family gathered. Kamarija and divanhana, the semi-open spaces on a first floor, which served as transitional spaces from the interior to the exterior, had a private character, and were used mainly for rest and enjoying the view of the bazaar, or the view of nature [11], [15].

The main living rooms in the house called halvat and čardak had a multifunctional character. Flexible use of the rooms was obtained by reducing the furniture to two basic fixed elements and mobile furniture, which was brought into the room when needed. This interior design enabled the reduction of the size of the room to a minimum. This is important from the aspect of energy savings, because large spaces are requiring more energy for heating and cooling.

4.1. Building form and orientation

The basic design concept of analyzed houses was the separation of private, family life from noisy, public life on the street. Therefore, houses were oriented towards inner courtyards and gardens. Secondly, there was the division of the houses into winter and summer quarters. Winter quarter is located on the ground floor and summer quarter is located on the first floor.

Winter quarters are more compact and closed with few smaller windows. The reason for such design approach was to reduce heat losses during the winter period. Negative aspect of such building design is reflected in limited heat gains from the sun. Additionally, the shadow is created from kamarija and divanhana on the first floor which reduces solar heat gains even more [22]. This is especially emphasized in Sabura's house, where kamarija is on the south side of the main living room. Also, fewer windows and shadows from the first floor are minimizing daylight harvesting and increasing the need for artificial lighting.

Summer quarters, where closed and semi-open spaces intertwine, are playful and more open, with many large windows, oriented mainly towards the south, west, and east. In this way, interiors of the analyzed houses are perceiving a lot of natural light during the day, which is positive from the bioclimatic aspect because it can reduce the need for artificial lighting. Considering that the rooms in summer quarters are accessed through semi-open spaces, they are not exposed to direct sunlight from the south, in order to keep the rooms as cool as possible [22].

4.2. Local building materials and construction

All three analyzed houses have the same structural system, typical of vernacular residential architecture from the Ottoman period in Sarajevo. Materials used for construction were stone, adobe brick, and wood. Stone was used for the building's foundations and the walls of auxiliary rooms on the ground floor [23].

The walls on the ground floor, which were intended for living during the winter, are thick and made of adobe brick, reinforced with wood beams [23]. The thermal mass of the thick adobe walls ensures minimal temperature oscillations during the day. The walls can absorb the heat from the heating device and from the sun during the day, and then slowly release it into the room during the night. This is an important part of the bioclimatic design which provides a continuous comfortable indoor climate in winter [22].

Wood was extensively used in the exterior and interior. The construction of the walls on the first floor, which was intended for living during the summer, is a wooden skeleton with one layer of adobe brick infill [23]. Unlike the walls on the ground floor, these walls are thin and light with low thermal mass, and therefore provide fast cooling over the night. [22]

All horizontal constructions were made of close-set half-logs, covered with clay mixed with lime. The roofs are hipped, with wooden structures, covered with hollow tiles. All windows are with wooden frames and are single-glazed. [23]

In the interior, the ceilings were covered with wooden laths. The floors were made of wide deal boards.

All materials used for construction had „artisanal production“ [5, p. 44], meaning that, stone, adobe brick, and wood were from the domestic market, and they were the primary building materials used in B&H.

4.3. Natural cooling and ventilation

Several different sun-shading elements were used in the summer quarters of the houses for the protection of inner spaces from overheating during the summer.

In all three analyzed houses, the main sun-shading element used on windows was mušebak, Figure 5.

Figure 5. Mušebak on the windows of kamarija [24]

Figure 6. Wooden shutters on windows [25]

Figure 7. Iron window shutters on windows (Authors, 2022.)

Mušebak is a wooden lattice element that has a double purpose. First, it acts as a vernacular version of a modern double-skin facade. In the space between mušebak and the window, due to the shade and lower temperature, airflow is enabled [22]. Secondly, the semi-transparent structure of the mušebak is reducing solar radiation that enters the room, while providing optimal natural lighting. Beside mušebak, in Alija Đerzelez house, nontransparent wooden shutters, placed on the inner side of the windows were used, Figure 6. In Svrzo's house, on some windows, iron window shutters, placed on the outer side, were used, Figure 7. The main purpose of the iron window shutters was to secure houses from intruders, but they were also used as protection from strong winds and storms, or direct solar radiation during the summer.

In all three analyzed houses sun shading of the first floor is additionally provided by roof eaves. The doksat on the first floor is providing sun shading to the rooms on the ground floor, but also an appropriate shading for pedestrians, as the first floor is overhanging the street [22]. All the streets (mahala) are very narrow and surrounded by houses with overhanging first floors. This spatial organization of the residential quarters within the city gives pedestrians a place to hide from the heat during the hot summer days.

Natural ventilation was achieved through a thoughtful building design. Elements used for achieving qualitative natural ventilation of the summer quarters were: semi-open spaces, careful disposition and the size of the windows, the inner spaces organization, and courtyards and gardens.

In the semi-open spaces, divanhana (Figure 8) and kamarija (Figure 9), due to a shade and lower temperature, airflow is established, and solar radiation is reduced, creating a living space with a pleasant climate. Careful disposition and sizing of the windows enable cross ventilation through windows that are open at the same time throughout the house during the summer [22]. In Sabura's house, on the upper part of the walls, above the windows, there are holes which are enabling airflow even when the windows are closed, Figure 10.

The rooms placed in the middle of the house were cross ventilated through the corridor called hajat and the kitchen (mutvak), in which the windows were always opened. Vertically, the ventilation was achieved through the hajat and the kitchen which has ventilation openings in the roof to allow the smoke and steam from cooking to escape. Therefore, the houses are ventilated in both ways, horizontally and vertically.

Figure 8. Divanhana in Sabura's house[26]

Figure 9. Kamarija in Svrzo's house (Authors, 2022.)

Figure 10. Ventilation elements in the walls above windows [27]

The courtyards and gardens contribute significantly to the process of natural cooling of the houses during the summer, Figure 11. Trees, fountains and wells were the key elements of every courtyard. Gardens were enriched with flowers and fruit trees. Planting deciduous trees to shade south, east, and west side of the building is beneficial in the summer by creating a refreshing effect. Dense tree canopies are providing a natural shadow. They also regulate wind mitigation and its direction, which improves natural ventilation. In winter, deciduous trees shed their leaves and allow sunlight to reach the winter quarters of the houses. Therefore, they do not obstruct the utilization of solar heat gains for passive heating.

Figure 11. Integration of the greenery in Svrzo's house complex, small garden - left, Men's courtyard – right [28]

Figure 12. Water fountain in the garden (Sourse: Authors, 2022.)

Water elements, in the form of fountains, through the process of evaporation, additionally contribute to lowering the temperature during the hot summer days, Figure 12.

5. DISCUSSION

Examples of analyzed vernacular houses show the importance of proportions, scale, and volume in architecture for users and visitors in creating a personal impression and a pleasant experience of a certain built environment. The conceptual approach that architecture is built from nature and the environment, represents the utilization of bioclimatic elements such as the use of local building materials, simple, cubic forms, adaptability to a specific location and climate, and passive strategies for cooling and natural ventilation (wind, vegetation, local breezes, water). Such design, with a tendency to achieve a balance of aesthetics and function, without comprising nature and needs of people, represents an important basis for reinterpretation of heritage values into contemporary architecture, by improving the sustainable design with continuous progress. The findings presented in this paper do not propose rejection of modern technological achievements and pure replication of the good vernacular building practices. In order to achieve sustainable built environment, we need new architectural perspective in which valuable traditional knowledge is combined with new industrial innovations and emerging technology. Also, negative aspects of the vernacular building design which are reflected in the use of building materials with thermal characteristics that do not meet today's standards of energy efficient architecture, insufficient use of passive solar heat gains in winter and uncontrolled infiltration losses need to be improved in a contemporary bioclimatic building design. The guidelines for the contemporary bioclimatic building design, based on the positive characteristics found in vernacular architecture, as a model for future, are shown in Table 1.

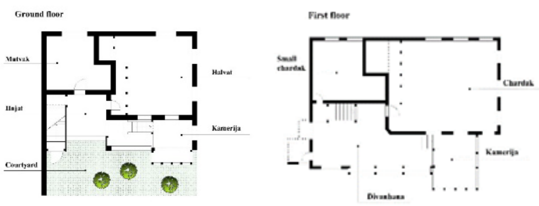
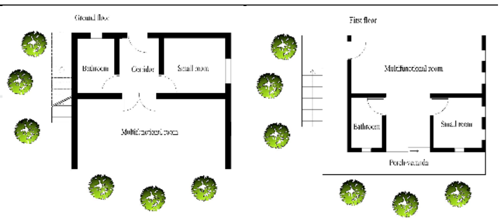
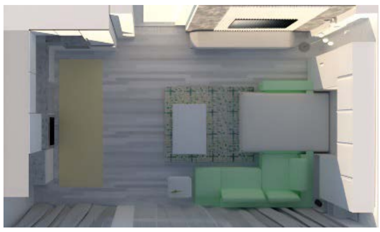
From the analysis presented in this paper, it can be concluded that the most significant characteristic of vernacular houses from Ottoman period in Sarajevo is the division of the houses in winter and summer quarters and their adaptation to seasonal conditions. Secondly, the multifunctional character of the rooms makes a significant contribution to the overall reduction of required energy for heating and cooling through optimization of the room dimensions without interrupting the comfort of living for the tenants. This can be achieved by introducing multifunctional furniture, which can change its purpose during the day. A schematic floor plan representation of a proposed contemporary house, based on these principles, and based on the guidelines for contemporary building design, is shown in Table 2. Following guidelines were taken into account: multifunctional character of the rooms, division of the house into winter and summer quarters, winter quarter oriented towards south, with large windows, closed towards north, summer quarter opened towards north and east, with large windows, few smaller windows towards south, semi-open spaces in summer quarter in the line of the ground floor, deciduous trees on the west and south side for natural cooling.

Table 9. The guidelines for the contemporary bioclimatic building design, based on vernacular architecture

Vernacular building design	The guidelines for contemporary building design
building in a human scale	building in a human scale
multifunctional character of the rooms	multifunctional character of the rooms
division of the house into winter and summer quarters	division of the house into winter and summer quarters
compact and closed winter quarter with fewer windows	winter quarter oriented towards south, with large windows, closed towards north with few smaller windows
playful and open summer quarter with many large windows, oriented towards the south, west, and east	summer quarter opened towards north and east, with large windows, few smaller windows towards south
sun shading elements on windows in summer quarter	sun shading elements on windows in summer quarter
natural cross ventilation in horizontal and vertical direction	natural cross ventilation in horizontal and vertical direction
uncontrolled ventilation, high infiltration losses	controlled ventilation, good air-tightness of building envelope elements
the protruding semi-open spaces in summer quarter on the first floor, creating shadow for the winter quarter on the ground floor	semi-open spaces in summer quarter in the line of the ground floor, without obstructing heat gains from the sun in winter quarter
courtyards and gardens for natural cooling	courtyards and gardens for natural cooling
natural, locally found building materials with low embodied carbon, recyclable	natural, locally found building materials with low embodied carbon, recyclable
high thermal mass of the walls in winter quarter	high thermal mass of the walls in winter quarter
low thermal mass of the walls in summer quarter	low thermal mass of the walls in summer quarter

no thermal insulation in building envelope elements	good thermal insulation of building envelope elements, use of organic, natural insulation materials
single-glazed windows with wooden frame	triple-glazed windows with wooden frame

Table 2. The proposed contemporary building design, based on vernacular architecture

The principles of vernacular building design	**The proposed contemporary building design**
 *Sabura's house: left – winter quarter, right – summer quarter*	 *Contemporary model house: left – winter quarter, right – summer quarter*
 *Multifunctional room in Svrzo's house during the day*	 *Multifunctional room in winter quarter during the day*
 *Multifunctional room in Svrzo's house at night*	 *Multifunctional room in winter quarter at night*

6. CONCLUSION

Bioclimatic principles recognized in the analyzed vernacular houses from the Ottoman period in Sarajevo can be used as an inspiration for contemporary architecture. These vernacular houses show that in the old times, the approach to urban settlement planning was carefully thought out with great respect toward people's needs on one side and towards nature on the other side. The analysis showed that in vernacular houses, a high standard of living was achieved. Opposite of that holistic approach, Sarajevo today is faced with increased urban development and poor living standard, which is the result of unsustainable urban planning. The right approach to overcome the negative environmental impact of unsustainable urban planning, which is a major problem nowadays, is to learn from the past and to interpret all the good traditional principles through a new contemporary design. Incorporation of bioclimatic principles from the vernacular building into modern building design, such as the use of local and natural building materials, the position of the building with respect to nature, consideration of passive systems for cooling in a design process, integration of greenery, and water, multifunctional spaces that will optimize the room size without degrading the quality of living, and the division of the spaces in winter and summer quarters, can result in the high-quality sustainable modern architecture.

REFERENCES

[1]. A. Visic, “Pametni gradovi: Implementacija tehnologija za održivi razvoj” (“Smart cities: implementing technologies for sustainable development”), Master's thesis, University of Split, Faculty of Economics, Split, 2021.

[2]. H. Ritchie, M. Roser. (2018) Urbanization, Our World in Data. [Online]. Available: https://ourworldindata.org/urbanization

[3]. K. Boakey M. Bovbjerg, Schuna J., et al, “Urbanization and physical activity in the global prospective urban and rural epidemiology study”, *Scientific Report*, vol. 13, 290, 2023.

[4]. H. M. Mazraeh, M. Pazhouhanfar, “Effects of vernacular architecture structure on urban sustainability case study: Qeshm Island, Iran”, *Frontiers of Architectural Research*, vol. 7 (1), pp. 11-24, 2018.

[5]. M. Correia, *et al*, *Versus, Heritage for tomorrow: Vernacular knowledge for sustainable architecture*, Ed. Firenze: Firenze University Press, p. 286, 2014, http://digital.casalini.it/9788866557425.

[6]. GreenTourism Homepage. [Online]. Available: http://www.greentourism.eu/en/Post/Name/SustainableTourism

[7]. M. Rahim, “Bioclimatic and sustainable features on vernacular architecture in Ternate”, in *IOP Conference Series: Materials Science and Engineering* 1212 012006, 2022.

[8]. M. Philokyprou, M., A. Michael, A, “Evaluation of the environmental features of vernacular architecture. A Case Study in Cyprus”, *International Journal of Heritage in the Digital Era*, vol. 1(1), pp. 349–54, 2012.

[9]. J. Kraemer, J, “Architecture destroys nature? Rebuilding the human-nature connection”, Master’s thesis, Chalmers School of Architecture, Gothenburg, Sweden, 2020.

[10]. A. T. Nguyen, S. H. Truong, D. Rockwood, D, and A. D. Tran Le, “Studies on sustainable features of vernacular architecture in different regions across the world: A comprehensive synthesis and evaluation”. *Frontiers of Architectural Research*, vol. 8 (4), pp. 535-548, 2019.

[11]. Bosanskohercegovačka arhitektura (Architecture of Bosnia and Herzegovina). [Online]. Available: https://www.wikiwand.com/sh/Bosanska_arhitektura#Aktuelni_arhitektonski_pravci

[12]. A. Bejtić, *Spomenici Osmanlijske arhitekture u Bosni i Hercegovini* (Monuments of Ottoman architecture in Bosnia and Herzegovina), Contributions to Oriental Philology, Oriental Institute, Sarajevo, pp. 229-297, 1952.

[13]. A. Pašić (n.d.) Arhitektura Bosne i Hercegovine, Osmanski period (1463-1878): Stanovanje (Architecture of Bosnia and Herzegovina, Ottoman period (1463-1878): Housing). [Online]. Available: https://www.scribd.com/doc/109135013/04-Arhitektura-BiH-1463-1878-Stanovanje

[14]. B. Trapara (2017). Kako razumjeti sekvence i mjerilo u *arhitekturi* (How to understand sequences and scale in architecture). [Online]. Available: https://aabh.ba/kako-razumjeti-sekvence-i-mjerilo-u-arhitekturi/

[15]. E. Temim (2008). Bosanska cvjetna avlija (Bosnian flower courtyard). [Online]. Available: https://www.avlija.me/kulturna-bastina/bosanska-cvjetna-avlija, last accessed 2022/12/6.

[16]. G. I. Ozorhon, G., I. F. Ozorhon, “Learning from Mardin and Cumalikizik: Turkish Vernacular Architecture in the context of sustainability”, *Arts*, vol. 3 (1), pp. 175-189, 2014.

[17]. T. Jažić (2020). Kult Žive Tekuće Vode – O Sarajevskim česmama i bunarevima (The Cult of Living Running Water - About Sarajevo's fountains and wells). [Online]. Available: https://tarikjazic.wordpress.com/2020/04/19/kult-zive-tekuce-vode-o-sarajevskim-cesmama-i-bunarevima/

[18]. A. Korjenic, S. Klarić, “The revival of the traditional Bosnian wood dwellings”, *Energy Efficiency*, vol. 4 (4), pp. 547-558, 2011.

[19]. K. Matolcsy, *et. al*, “Guide for bioclimatic design”, European Union, PIME’S project, pp. 1-139, 2015. [Online]. Available https://smart-cities-marketplace.ec.europa.eu/sites/default/files/pimes_guide_for_bioclimatic_design.pdf

[20]. Kuća Alije Đerzeleza, Heroja usmenih legendi iz 17. vijeka (The house of Alija Đerzelez, the hero of oral legends from the 17th century), [Online]. Available: http://miruhbosne.com/kuca-alije-djerzeleza-heroja-usmenih-legendi-iz-17-vijeka/

[21]. Historijski lokalitet Kovači (The historical site of Kovači). [Online]. Available: https://trail.viadinarica.com/bs/point/historijski-lokalitet/kovaci/16487266/#dmlb=1

[22]. S. Martinovic, N. Zecevic, A. Salihbegovic,” Vernacular Residential Architecture in the Context of Sustainability – Case Study of Svrzo's House Complex”, *Journal of Sustainable Architecture and Civil Engineering.* [Accepted for publishing on 2023/04/03]

[23]. Commission to Preserve National Monuments. [Online]. Available: http://old.kons.gov.ba/main.php?mod=spomenici&extra=Odluke&blok=2&indexGrad=1&lang=4&idGrad=86, last accessed 2022/12/22.

[24]. Kuca Alije Dzerzeleza (Alija Dzerzelez house). [Online]. Available: https://www.tripadvisor.co/LocationPhotoDirectLink-g294450-d8660443-i152901500-Kuca_Alije_Derzeleza-Sarajevo_Sarajevo_Canton_Federation_of_Bosnia_and_H.html, last accessed 2022/12/28

[25]. Commission to Preserve National Monuments, the Architectural ensemble of the Alija Đerzelez house in Sarajevo. [Online]. Available: http://old.kons.gov.ba/main.php?id_struct=50&lang=4&action=view&id=2581

[26]. Obnovljena Saburina kuca: Primjer raskosne bosanske kuce (Renovated Sabura's house: An example of a luxurious Bosnian house). [Online]. Available: https://www.dominfo.ba/obnovljena-saburina-kuca-primjer-raskosne-bosanske-kuce/

[27]. A. Hadrović, A., “The Place of wood in the design of oriental type city houses in Sarajevo”, *International Journal of Scientific Engineering and Science*, vol. 6 (8), pp. 42-58, 2022.

[28]. M. Arslanović, Bosnian front yard and garden. [Online]. Available: https://www.bosnianexperiences.com/19-text-no03

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Investigation of Adsorption Behavior of Activated Carbon Obtained from Chamomile and Kinetic Studies

Sahra Dandil[1]

Abstract

The use of natural materials as an adsorbent in adsorption processes stands out because of their cheapness and high performance. In the study, the adsorption behavior of chamomile, which is a short-lived plant that can grow spontaneously in many places, as an adsorbent was studied. Dried natural chamomile and phosphoric acid (H_3PO_4) were mixed in a 2:1 ratio by mass for H_3PO_4:chamomile and kept at room temperature for 24 hours. Then the mixture was dried and kept in a nitrogen atmosphere at a heating rate of 10 °C/min at a flow rate of 100 mL/min at 600 °C for 1 hour. Then, the sample was washed with sodium hydroxide (NaOH) and distilled water, respectively, and dried in an oven. The prepared activated carbon was used in the removal of crystal violet dye from aqueous solutions. Adsorption studies were followed for 300 minutes for pH 1-7 at 20 ppm dye concentration and 1 g/L adsorbent dosage. The concentration changes were followed by taking samples from the dye solutions at certain time intervals and the behavior of the processes was revealed in 300 minutes. Accordingly, at the end of 300 minutes, the highest removal percentage was obtained as 93.11% at pH 7. The behavior of the adsorption process over time was investigated by kinetic studies. Pseudo-first-order, pseudo-second-order and intra-particle diffusion kinetic models were examined and the regression coefficients (R^2) of these models were determined. Accordingly, the R^2 values for the pseudo-first-order, pseudo-second-order and intra-particle diffusion model were obtained as 0.969, 0.9994 and 0.9986 and 0.9936, respectively, and according to the highest R^2 values, the process was found to be compatible with the pseudo-second-order kinetic model and intra-particle diffusion model. According to the results; it was determined that the activated carbon obtained with chamomile showed effective behavior in the adsorption of crystal violet dye with high removal values.

Keywords: Activated carbon, Adsorption, Chamomile, Crystal Violet

1. INTRODUCTION

Adsorption is a surface phenomenon in which ions, atoms or molecules are transferred from a liquid bulk to a solid surface and adhere to the surface physically or chemically. The process proceeding in this way reaches equilibrium after a while. Also, the reverse of this process (desorption) is possible [1]. In general terms, the molecules are called adsorbate and solid adsorbent. The efficiency of the adsorption processes depends on the properties of the adsorbate and the adsorbent and the interaction between them. It is desirable for an adsorbent to have high porosity and surface area. Examples of typical adsorbents are activated carbon, zeolites, activated alumina and bentonite [2].

Activated carbon is a carbonaceous material with high surface area and porosity [3]. It can be synthesized by chemical or physical methods [4]. Activated carbon synthesis includes carbonization and activation steps [5]. In physical activation, the material is carbonized in a neutral atmosphere and then activated in oxidizing gases in the range of 800–1100 °C. Chemical activation involves impregnating the material with chemicals and then heating the dried sample at temperatures ranging from 400 to 900 °C [6].

Chamomile is a plant of the family Asteraceae [7]. The plant consists of an erect stem, a yellow centre and white petals and grows to a height of 10-80 cm [8],[9]. It is an annual or perennial plant [10]. Chamomile has

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been used medicinally for thousands of years by ancient Greek, Roman and Egyptian cultures [11]. It has been claimed to have a calming effect and has been used for insomnia and sedation [12]. It is also widely used in herbal tea, cosmetics and aromatherapy [13]. Although it has traditional uses, it is claimed that it also has negative effects in terms of health, and it is reminded that there are limited scientific studies on drug interactions and side effects.

In this study to obtain an effective and low-cost adsorbent, chamomile was used to prepare activated carbon. The phosphoric acid (H_3PO_4) was used as an activating agent and synthesized activated carbon was used in crystal violet dye adsorption from aqueous solutions. The effective parameters (pH and time) and kinetic studies of the adsorption processes were investigated.

2. MATERIALS AND METHODS

2.1. Materials

Natural chamomile was purchased from a local market in Bilecik. Dry chamomile was ground and grains in the 0.250-0.425 mm size range were selected by sieving. Crystal violet dye was supplied from Fluka. Orthophosphoric acid (H_3PO_4, 85%) and sodium hydroxide (NaOH) pellets were purchased from Carlo Erba.

2.2. Methods

The activating agent H_3PO_4 and chamomile were mixed in a mass ratio of 2:1 for H_3PO_4:chamomile. The chamomile was treated with H_3PO_4 at room temperature for 24 hours. The mixture was dried in an oven. The sample was taken in a tubular oven and kept in a nitrogen atmosphere at 600 °C at a heating rate of 10 °C/min at a flow rate of 100 mL/min for 1 hour. Then, the sample was washed with NaOH and distilled water, respectively. The wet sample was dried in an oven at 105 °C and the activated carbon was obtained.

The activated carbon was used in the adsorption of crystal violet dye. Experiments were performed with 50 mL dye solutions in a shaker (Thermal H11960) at 200 rpm and room temperature. The experiments were followed at a pH range of 1-7, 20 ppm dye solution concentration, and 1 g/L adsorbent dosage.

Absorbance values of the samples taken at certain time intervals were determined by an Ultraviolet/Visible region (UV-VIS) spectrophotometer (Perkin Elmer, Elmer Analyst 800). The spectrophotometer was used at 590 nm which is the wavelength that crystal violet had maximum absorbance.

The efficiency of the adsorption process was determined by some adsorption terms. Some calculations were used for the terms. Removal efficiency values of the process were determined by using Equation (1):

$$\text{Removal efficiency (\%)} = \frac{(C_0 - C_e)x100}{C_0} \quad (1)$$

where; Co and Ce are the dye concentration at initial and equilibrium (mg/L), respectively.

The adsorption capacity was also obtained by Equation (2) given below:

$$q_e = \frac{(C_0 - C_e)xV}{W} \quad (2)$$

where; qe is the adsorption capacity (mg/g), V is the volume (L), W is the mass of the adsorbent (g).

Kinetic study of the process was examined with the pseudo-first-order kinetic model, the pseudo-second-order kinetic model and the intra-particle diffusion model. The kinetic model equations are put in the order below:

Pseudo-first-order kinetic model: $$\log(q_{e-}\, q_{t}) = \log q_e (\frac{k_1}{2,303})t \quad (3)$$

Pseudo-second-order kinetic model: $$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \quad (4)$$

Intra-particle diffusion model: $$= k_{int} t^{0,5} + C \quad (5)$$

where; t is time (min), qt is the amount of adsorbate at time t (mg g^{-1}), k_1, k_2, and k_{int} are the rate constants of pseudo-first-order kinetic model (min^{-1}), pseudo-second-order kinetic model (g mg^{-1} min^{-1}), and intra-particle diffusion model (mg/g.$min^{0,5}$), respectively, and C is the constant [14].

3. RESULTS AND DISCUSSION

To determine the concentration of the crystal violet solutions at time t, samples were taken from the solutions at certain time intervals. The UV/Vis Spectrophotometer was used to determine the absorbance values of the samples and these absorbances were converted to concentration values by using the calibration graph shown in Figure 1.

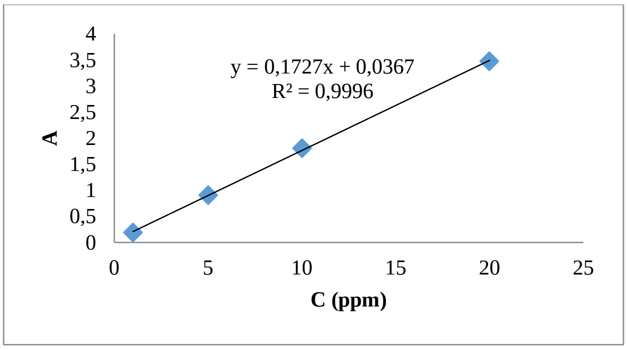


Figure 1. Calibration graph of Crystal Violet dye

In the adsorption experiments, the crystal violet dye removal behavior of the activated carbon obtained from chamomile in the pH range of 1-7 was investigated. The change of removal efficiencies at each pH value was followed over time. Figure 2 presents the removal efficiency- time graph for the adsorption process. As seen in Figure 2, for each pH value, regular changes were observed over time. It is observed that the removal rate increase rapidly in the first 2 hours, and the removal continue to increase even though the increase rate decreases after 2 hours. The processes were followed for 300 minutes. After 300 minutes, the removal efficiencies were obtained as 86.49, 85.61, 66.95, 85.30, 91.08, 91.12 and 93.11 for pH 1, 2, 3, 4, 5, 6, and 7, respectively. Accordingly, the highest removal was obtained at pH 7. However, as seen in Figure 2, it was also determined that the process reached equilibrium at pH 7 in 300 minutes.

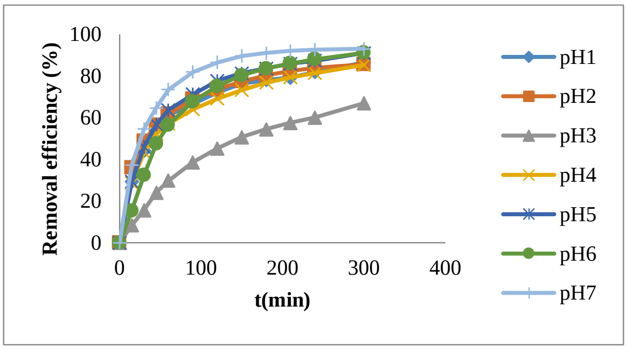
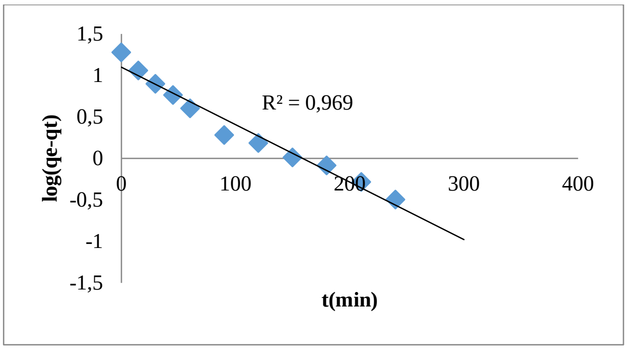
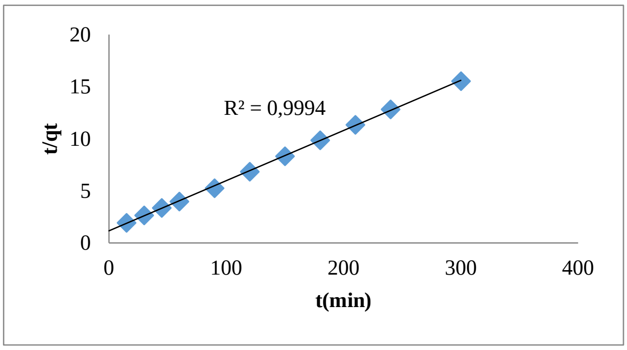


Figure 2. Removal efficiency (%)-t(min) graph for each pH

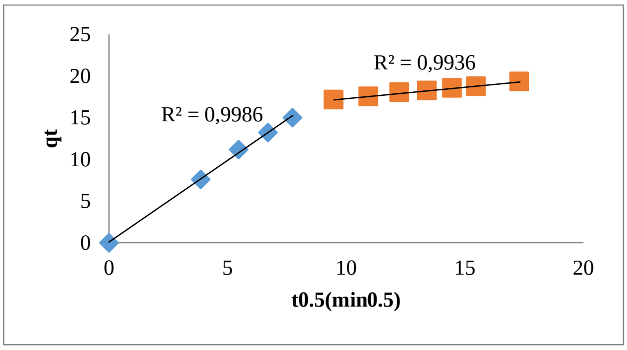
The dye adsorption process was evaluated in terms of its behavior against time using kinetic models. The pseudo-first-order kinetic model, the pseudo-second-order kinetic model and the intra-particle diffusion model were used as kinetic models for the Crystal Violet dye removal process by the activated carbon obtained from chamomile. The graphs and regression coefficients (R^2) of the kinetic models are seen in Figure 3. As seen in Figure 3, R^2 values of the pseudo-first-order, pseudo-second-order and intra-particle diffusion model were obtained as 0.969, 0.9994 and 0.9986 and 0.9936, respectively. According to the R^2 values, the highest value was obtained for the pseudo-second-order kinetic model and intra-particle diffusion model. This explained that the process was compatible with the pseudo-second-order kinetic model and intra-particle diffusion model. The pseudo-second-order kinetic model describes that the rate-limiting step is chemical adsorption and defines that the adsorption rate is related to adsorption capacity. Adsorbate concentration is ineffective on adsorption rate [15]. And, for the intra-particle diffusion model, multiple linearity presents that different steps active for the process. The first linearity shows the external surface adsorption, and the other linearity is related to intraparticle diffusion as gradual adsorption [16]. The kinetic parameters of the kinetic models were shown in Table 1.



(a)



(b)



(c)

Figure 3. (a) pseudo-first-order kinetic model, (b) pseudo-second-order kinetic model, (c) intra-particle diffusion model graphs

Table 1. Kinetic parameters of the kinetic models

Pseudo-first order kinetic model	k_1 (x10^3) (min^{-1})	15.89
	$q_{e, cal}$ (mg g^{-1})	12.56
	R^2	0.969
Pseudo-second-order kinetic model	k_2 (x10^3) (g mg^{-1} min^{-1})	1.99
	$q_{e ,cal}$ (mg g^{-1})	20.79
	R^2	0.9994
Intra-particle diffusion model	R^2_1	0.9986
	R^2_2	0.9936
	$k_{int,1}$ (mg $g^{-1}min^{-0,5}$)	1.96
	$k_{int,2}$ (mg $g^{-1}min^{-0,5}$)	0.27
	C_1 (mg g^{-1})	0.072
	C_2 (mg g^{-1})	14.53

4. CONCLUSIONS

In the study, the adsorption behavior of chamomile, which is a short-lived plant that can grow spontaneously in many places, as an adsorbent was studied. The synthesized activated carbon was used in the crystal violet dye removal from aqueous solutions. Adsorption studies were followed for 300 minutes for pH 1-7 at 20 ppm dye concentration and 1 g/L adsorbent dosage. At the end of 300 minutes, the highest removal percentage was obtained as 93.11% at pH 7. In the kinetic studies, pseudo-first-order, pseudo-second-order and intra-particle diffusion kinetic models were examined. The process was found to be compatible with the pseudo-second-order kinetic model and intra-particle diffusion model. The pseudo-second-order kinetic model indicated that the rate-limiting step is chemical adsorption. Intra-particle diffusion model explained that external surface adsorption and intraparticle diffusion are effective in the process. According to the results; it was determined that the activated carbon obtained with chamomile showed effective behavior in the adsorption of crystal violet dye with high removal efficiencies.

REFERENCES

[1]. Y. Artioli, *Encyclopedia of Ecology,* S. E. Jørgensen, B. D. Fath, Ed. Amsterdam, Netherlands: Elsevier, 2008.

[2]. R. Cossu, H. Ehrig, A. Muntoni, *Solid Waste Landfilling*, R. Cossu, R. Stegmann, Ed. Amsterdam, Netherlands: Elsevier, 2018.

[3]. D. A. Meadows, D. E. Clouse, S. Adhikari, and V. A. Davis, "Prediction of structural properties of activated carbons derived from lignocellulosic biomass components using mixture design of experiments", *Materials Chemistry and Physics*, vol. 303, pp. 127715, 2023.

[4]. S. Kyrii, Z. Maletskyi, N. Klymenko, H. Ratnaweera, T. Mitchenko, T. Dontsova, and I. Kosogina, "Impact of modification by red mud components on the sorption properties of activated carbon", *Applied Surface Science Advances*, vol. 16, pp. 100412, 2023.

[5]. M. S. Reza, C. S. Yun, S. Afroze, N. Radenahmad, M. S. A. Bakar, R. Saidur, J. Taweekun, and A. K. Azad, "Preparation of activated carbon from biomass and its' applications in water and gas purification, a review", *Arab Journal of Basic and Applied Sciences*, vol. 27(1), pp. 208-238, 2020.

[6]. Z. Heidarinejad, M. H. Dehghani, M. Heidari, G. Javedan, I. Ali, and M. Sillanpää, "Methods for preparation and activation of activated carbon: a review", *Environmental Chemistry Letters*, vol. 18, pp. 393-415, 2020.

[7]. A. Banerjee, M. S. Pavane, L. H. Banu, A. S. R. Gopikar, K. R. Elizabeth, and S. Pathak, *Stem Cells and Aging,* S. Pathak, A. Banerjee, Ed. Amsterdam, Netherlands: Elsevier, 2021.

[8]. H. Ghizlane, and B. Aziz, *Fruits, Vegetables, and Herbs,* R. R. Watson, and V. R. Preedy, Ed. Amsterdam, Netherlands: Elsevier, 2016.

[9]. (2023) The wikifarmer website. [Online]. Available: https://wikifarmer.com/german-chamomile-plant-information/

[10]. Y. L. Dai, Y. Li, Q. Wang, F. J. Niu, K. W. Li, Y. Y. Wang, J. Wang, C. Z. Zhou, L. N. Gao, "Chamomile: A Review of Its Traditional Uses, Chemical Constituents, Pharmacological Activities and Quality Control Studies", *Molecules*, vol. 28(1), pp. 133, 2022.

[11]. G. M. Kapalka, *Nutritional and herbal therapies for children and adolescents: A handbook for mental health clinicians*, G. M. Kapalka, Ed. Amsterdam, Netherlands: Elsevier, 2009.

[12]. R. Kolanos, and S. A. Stice, *Nutraceuticals*, R. Gupta, R. Lall, A. Srivastava, Ed. Amsterdam, Netherlands: Elsevier, 2021.

[13]. J. K. Srivastava, and S. Gupta, *Foods and dietary supplements in the prevention and treatment of disease in older adults*, R. R. Watson, Ed. Amsterdam, Netherlands: Elsevier, 2015.

[14]. S. Dandil, D. Akin Sahbaz and C. Acikgoz, "Adsorption of Cu (II) ions onto crosslinked chitosan/Waste Active Sludge Char (WASC) beads: Kinetic, equilibrium, and thermodynamic study", *International journal of biological macromolecules*, vol. 136, pp. 668-675, 2019.

[15]. T. R. Sahoo, and B. Prelot, *Nanomaterials for the detection and removal of wastewater pollutants*, B. Bonelli, F. Freyria, I. Rossetti, R. Sethi, Ed. Amsterdam, Netherlands: Elsevier, 2020.

[16]. F. C. Wu, R. L. Tseng, and R. S. Juang, "Initial behavior of intraparticle diffusion model used in the description of adsorption kinetics", *Chemical engineering journal*, vol. 153(1-3), pp. 1-8, 2009.

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The Detection and Analysis of Antidepressants in Erzurum Urban Wastewater Treatment Plant

Nuray Erdogdu[1], Zeynep Eren[2]

Abstract

In this study, it was aimed to detect and monitor three target residuals compounds consisting of Mirtazapine, Citalopram, and Doxepin belonging to the antidepressant group of pharmaceuticals, whose use has increased rapidly after the Covid-19 pandemic during 12 months between December 2020-November 2021 post-pandemic period in Erzurum Urban WWTP. Since Erzurum Urban WWTP is a biological treatment plant, after the determination of the target antidepressant compounds in the samples taken from the wastewater inlet and outlet before the discharge points, their treatability in the facility was also examined. Samples were first concentrated with ethyl acetate (EtOAc) using the liquid-liquid extraction method and then it was analyzed at the µg/L level via LC-MS/MS method. Based on the analysis results, the treatment efficiency of three target pharmaceutical compounds in the facility was calculated. Treatment efficiencies were calculated as 0.252-4.149% for Mirtazapine, 4.295-5.421% for Citalopram, and 0.019-1.049% for Doxepin in a total 12-month monitoring period. Considering the treatment efficiencies of the plant operating parameters over 90% and the low treatment efficiency of the target AD compounds, it has been shown that the plant operating parameters have almost no effect on the treatability of the target compounds.

Keywords: Pharmaceuticals, Wastewater, WWTPs.

1. INTRODUCTION

The Covid-19 epidemic, which caused the declaration of a global pandemic on March 11, 2020 and caused the death of more than six and a half million people, has gone down in history as one of the biggest crises on a global scale [1]. The Covid-19 pandemic, which caused the implementation of quarantine conditions all over the world and a full closure for about 6 months, has brought about important psychological disorders that cause depression, anxiety disorders, insomnia, memory disorders, confusion, emotional balance disorders, trauma and post-traumatic stress in individuals. Although these processes do not show parallelism in all countries, they caused the widespread use of AD in the society and 20% more AD use in 2020 compared to the 2015-2019 period. These rates increased to 30% in the last two months of 2020 [2]. Many studies reveal that the Covid-19 pandemic has triggered a sharp increase in mental health problems, and therefore the use of AD as first-line therapy for these disorders is supported [3]. Widespread use of AD in society is associated with low work productivity, high healthcare costs, medical expenses and social costs. With the additional burden of the pandemic, WHO has stated that by 2030, depression will be the mental disorder with the highest level of disability worldwide [4].

Since ADs generally have a high lipid solubility and only 5% of them are absorbed in the human body, they undergo biotransformation, leading to high excretion of the parent compound or metabolites, and then these compounds can easily reach the aquatic environment through the discharge of wastewater. Studies show that antidepressants are reported more in aquatic matrices because most wastewater treatment plants do not have

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the necessary processes to treat such persistent compounds that may pose a future risk. It has been stated that AD tends to be highly absorbed into soils and sediments due to their low biodegradability in aquatic environments. For this reason, both the increase in the number of ADs in wastewater and their environmental persistence and possible toxic effects on living organisms cause researchers to be more concerned and increase the number of studies in this field [5].

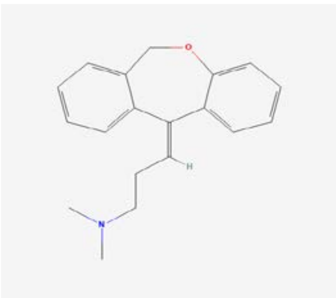
Of all AD target compounds, 51% were detected in the wastewater treatment plant inlet, 36% in the plant effluent, 20% in the downstream waters and 18% in the upstream water [6]. Limited number of studies on environmental persistence and ecotoxicity of ADs; reveals effects on gene transcription, reproductive cycles, predator defense and motility in aquatic species [7]. However, in relation to the increasing use of ADs during the pandemic process, studies on monitoring studies in wastewater, their fate in wastewater treatment plants, environmental degradation mechanisms, chronic toxicity on aquatic organisms, ecotoxicity of metabolites and combined toxicity of pharmaceuticals need to be increased.

Antidepressant/psychiatric medications are often prescribed to treat moderate or severe depression and anxiety. In addition, they are drug groups that are widely and effectively used in the treatment of sleep, eating disorders, pain syndromes, and in the treatment of many mood disorders and substance abuse. Antidepressant drugs function to inhibit the reuptake of serotonin, noradrenaline, and other neurotransmitters and directly or indirectly increase the effects of dopamine, norepinephrine, or serotonin in the brain. Antidepressants are the third most prescribed drug in the United States and are usually used for long treatment periods of at least 6 months. Antidepressants are excreted in the urine in their main forms or their metabolized forms after their intake by humans. For example, fluoxetine, an antidepressant drug, is metabolized by about 20-30% in the human body to form active metabolites, while the rest is transported to sewerage facilities unchanged [8,9,10,11].

From this point of view, the aim of the study is to determine that 3 pharmaceutical target compounds belonging to the AD group, consisting of Mirtazapine, Citalopram, Doxepin, were collected in monthly samples taken from Erzurum Urban Biological AAT in the period of December 2020-November 2021, including the post-pandemic period. detected and monitored. The treatability of these AD group compounds was analyzed within the scope of the study. The study also points out to reveal the importance of wastewater-based epidemiology method to determine the increase in the use of AD during the pandemic process.

2. MATERIAL AND METHODS

In this study, in order to determine and monitor 3 pharmaceutical drug compounds consisting of Mirtazapine, Citalopram, Doxepin (Figure 1) belonging to the AD group in Erzurum Biological WWTP (Figure 2), in the period of December 2020-November 2021, the inlet wastewater and outlet water of the facility in a 12-month period. Wastewater samples were taken by AAT technical personnel in accordance with the sampling conditions and delivered to the laboratory for rapid analysis. Samples that cannot be analyzed immediately at +4 ºC max. It was stored for 48 hours.

Doxepin	TSA group antidepressant
Molecule Structure	
Chemical Formula Molecular Weight Boiling point	$C_{19}H_{21}NO$ 279,4 g/mol 154-157 °C

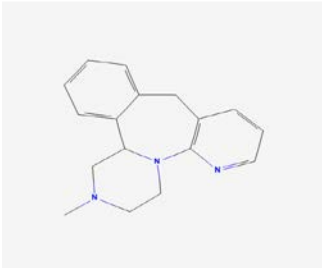
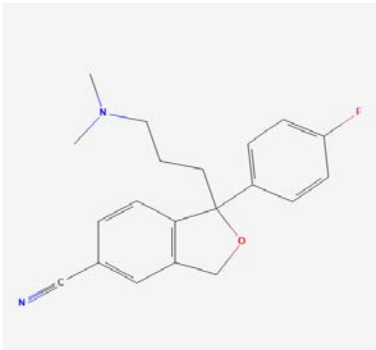
Intensity Metabolism Leap Bioavailability	1,2 g/cm^3 Liver Urine: 50%, Stool: Minor 13–45% (average 29%)
Mirtazapine	NaSSA group antidepressant
Molecule Structure	
Chemical Formula Molecular Weight Boiling point Intensity Metabolism Leap Bioavailability	$C_{17}H_{19}N_3$ 265,35 g/mol 432,4 °C 1,22 g/cm^3 Liver Urine: 75%, Stool: 15% %50
Citalopram	SSRI group antidepressant
Molecule Structure	
Chemical Formula Molecular Weight Boiling point Intensity Metabolism Leap Bioavailability	$C_{20}H_{21}FN_2O$ 324,4 g/mol 760 mmHg'de 428,3±45,0 °C 1,2±0,1 g/cm^3 Hepatic Urine %80

Figure 1. The Chemical Structure of Target Ads: Mirtazapine, Citalopram, Doxepin

Figure 2. Erzurum Biological WWTP, 2022.

LC-MS/MS analysis was performed on the samples taken from the discharge points. Mirtazapine, Citalopram, Doxepin pharmaceutical compounds in the inlet and outlet wastewater samples of the WWTP (Figure 3) were analyzed in LC-MS/MS (Agilent Technology 6460 Triple Quad LC/MC) device and the analyzes were performed in Atatürk University Central Laboratories (DAYTAM) service procurement. Liquid-liquid extraction method was used to separate and collect the pharmaceutical compound in the samples before the LC-MS/MS process (Figure 3). Considering the DAYTAM device methods for this study, ethyl acetate (EtOAc) was used for the recovery of the target compounds in terms of suitability for the method. With the liquid phase extraction process, the transition of the target compounds to the organic phase, ethyl acetate, was achieved. After the organic phase was completely removed in the evaporator, the compounds were completely dissolved in methanol added on the remaining solution and analyzed in an LC-MS/MS device.

Figure 3. Inlet and outlet wastewater samples of the WWTP

3. RESULTS AND DISCUSSION

AD drug active ingredients Mirtazapine, Citalopram, Doxepin concentrations in the inlet and outlet wastewater samples taken from the facility between December 2020 and November 2021 were analyzed by LC-MS/MS and were determined in Table 1 respectively shown.

Table 1. Input-Output Concentrations of AD

	Input Concentrations			Output Concentrations		
AD Compounds	**Mirtazepine µg/L**	**Citalopram µg/L**	**Doxepin µg/L**	**Mirtazepine µg/L**	**Citalopram µg/L**	**Doxepin µg/L**
December	1,276	0,127	0,411	-	-	-
January	1,245	0,128	0,414	-	-	-
February	1,276	0,152	0,414	-	-	-
March	1,265	0,161	0,417	1,246	0,152	0,413
April	1,240	0,131	0,413	1,259	0,133	0,413
May	1,308	0,150	0,410	1,254	0,143	0,418
June	1,270	0,127	0,411	1,238	0,136	0,414
July	1,246	0,131	0,413	1,239	0,160	0,419
August	1,251	0,130	0,414	1,248	0,140	0,417
September	1,325	0,140	0,415	1,294	0,146	0,412
October	1,305	0,152	0,410	1,260	0,145	0,413
November	1,334	0,154	0,409	1,305	0,162	0,410

In the first three months of the monitoring period, which started in December 2021, that is, in December, January, and February, only a monitoring study was carried out to determine whether AD drug active substances are only in wastewater and whether they reach visible concentrations. For this reason, the analysis of Doxepin, Mirtazapine, Citalopram compounds, which will be monitored as AD drug active ingredients, was carried out only in the inlet water samples of the facility. AD drug active substances, which can be observed at µg/L level for 3 months, were analyzed in wastewater samples taken from both inlet and outlet points of the facility in March, April, May, June, July, August, September, October, and November of 2022.

According to Table 1, the concentrations of three target drug active substances belonging to the antidepressant group in Erzurum Biological WWTP inlet wastewater samples were analyzed in the range of 1,240-1.334 µg/L of Mirtazapine, 0.127-0.161 µg/L of Citalopram and 0.409-0.417 µg/L of Doxepin. The concentrations of three targeted active substances belonging to the antidepressant group in the treated wastewater samples taken from the Erzurum Biological WWTP outlet discharge point; Mirtazapine 1.238-1.305 µg/L, Citalopram 0.133-0.162 µg/L, Doxepin 0.410-0.419 µg/L could be analyzed.

Input-output concentrations for Mirtazapine, Citalopram, and Doxepin substances were compared as follows. As a result, the output concentration is nearly no less than the input concentration. Therefore, target AD compounds can be defined as non-treatable in the Erzurum WWTP (Figure 4).

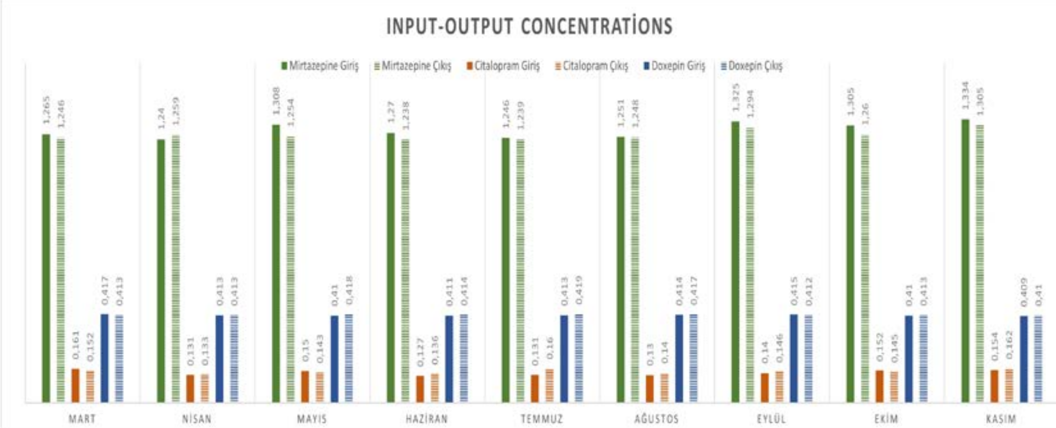


Figure 4. Comparisons of inlet and outlet concentration of target Ads.

As a result of the increasing use of antidepressants worldwide, it causes the active substances or metabolites of these drugs to be found in a wide distribution ratio in surface and ground waters. Antidepressants have been detected in various concentrations in aquatic organisms, with the highest bioaccumulation rate observed in organs with high fat content such as liver and brain [12]. This reveals that antidepressants, like most other pharmaceutical compounds, are not sufficiently purified in urban AATs. Literature studies reveal that antidepressants are neither easily hydrolyzed nor biodegraded in their AATs, they are only highly absorbed into activated sludge and are removed from water [13].

Antidepressants, like many other drug active substances, are excreted in the urine and mixed with the sewer after they are used by the body. Therefore, wastewater treatment plants and urban wastewater are the hottest spots for monitoring residues of these drugs [14,9]. Studies conducted in the USA show that sertraline, the most widely used drug substance belonging to the antidepressant group, has concentrations reaching 1 mg/L at AAT outlet discharge points. In a study conducted in Brazil, analysis of wastewater shows that there is an antidepressant concentration between 50-3,000 ng/L [15]. It is stated that these concentrations do not, however, cause fatal acute toxic effects on aquatic organisms. However, sertraline has also been reported to cause chronic toxic effects on aquatic organisms by affecting biochemical processes such as enzymatic activities, neurotransmitter concentrations, suppression of the escape reflex, changes in survival behavior against predators, decreased food consumption or behavioral changes such as increased swimming activity. In addition, there have been reports of the bioaccumulation of sertraline in a variety of aquatic organisms, including invertebrates such as crustaceans and fish and aquatic insects [16,17]. Sertraline is indicated as the antidepressant with the highest risk factor for aquatic life in most studies. This is followed by citalopram and bupropion. However, it is important to identify and quantify antidepressants in environmental matrices to fully assess their acute and long-term effects on the ecosystem.

It is possible that the disposal of antidepressants by absorption into activated sludge in WWTPs causes soil pollution in agricultural areas where these sludges are widely used, and these pharmaceutical compounds are mixed with surface waters as a result of drainage. Therefore, it is necessary to develop methods to analyze these compounds not only in the inlet and outlet water of the treatment plant, but also in the sludge [18]. There are studies in which antidepressants, which are difficult to treat in classical AATs, are eliminated by using various biological and physicochemical processes. These include aerobic granular sludge, selectively cultured microorganisms and advanced treatment methods such as phytoremediation coupled sequential batch reactor (SBR). In addition, new generation nanomaterial-based adsorbents and other physicochemical processes such as adsorption process, photocatalysis, photochemical oxidation, electrocatalysis, catalytic ozonation have remarkable purification efficiency in the degradation and mineralization of antidepressant compounds [19].

CONCLUSIONS AND RECOMMENDATIONS

Three pharmaceutical active substances belonging to different internal antidepressant groups were monitored in Erzurum Biological WWTP both in inlet raw wastewater samples and in treated water samples before discharge. It has been observed that the target compounds have little or no treatment efficiency and leave the plant without treatment.

In order to increase the treatability of drugs such as antidepressants, whose ecotoxic properties are frequently mentioned in the literature and which have extremely low treatability, advanced treatment methods such as ozonation should be integrated into treatment plants. However, laboratory studies should show that such advanced treatment methods do not produce more toxic by-products before being used in the field.

REFERENCES

[1]. WHO., WHO Coronavirus (COVID-19) Dashboard, https://covid19.who.int, Access Date: 7.01.2023., 2023..

[2]. Pazzagli, L., Reutfors, J., Lucian, E., Zerial, G., Perulli, A., Castelpietra, G., Increased antidepressant use during the COVID-19 pandemic: Findings from the Friuli Venezia Giulia region, Italy, 2015–2020. Psychiatry Research, 315, 114704, 2022.S. Zhang, C. Zhu, J. K. O. Sin, and P. K. T. Mok, “A novel ultrathin elevated channel low-temperature poly-Si TFT,” *IEEE Electron Device Lett*., vol. 20, pp. 569–571, Nov. 1999.

[3]. Khan, R., Saxena, A., Shukla, S., Assessment of the impact of COVID-19 lockdown on the heavy metal pollution in the River Gomti, Lucknow city, Uttar Pradesh, India. Environmental Quality Management, 31(4), 41-49, 2022.

[4]. World Health Organization WHO., World Health Organization Global Burden of Disease; 2004 Update. WHO: Geneva, Switzerland, 2008.

[5]. Diaz-Camal, N., Cardoso-Vera, J. D., Islas-Flores, H., Gómez-Oliván, L. M., Mejía-García, A., Consumption and ocurrence of antidepressants (SSRIs) in pre-and post-COVID-19 pandemic, their environmental impact and innovative removal methods: A review. Science of The Total Environment, 154656, 2022.

[6]. USEPA., Final Report: The Environmental Occurrence, Fate, and Ecotoxicity of Selective Serotonin Reuptake Inhibitors (SSRIs) in Aquatic Environments, https://cfpub.epa.gov/, Access Date: 21.12.2022, 2007.

[7]. Melchor-Martínez, E. M., Jiménez-Rodríguez, M. G., Martínez-Ruiz, M., Peña-Benavides, S. A., Iqbal, H. M., Parra-Saldívar, R., Sosa-Hernández, J. E., Antidepressants surveillance in wastewater: Overview extraction and detection. Case Studies in Chemical and Environmental Engineering, 3, 100074, 2021.

[8]. Yüzbaşıoğlu, D., Yılmaz, E. A., ve Fatma, Ü., Antidepresan ilaçlar ve genotoksisite. TÜBAV Bilim Dergisi, 9(1), 17-28, 2016.

[9]. Sarıkaya, M., Antidepresan ilaç kalıntılarının atık sularda izlenmesi için kromatografik yöntem geliştirilmesi. Yüksek lisans tezi, Sivas Cumhuriyet Üniversitesi Sağlık Bilimleri Enstitüsü, Sivas, Türkiye, 2020.

[10]. Khasawneh, O. F. S., Palaniandy, P., Occurrence and removal of pharmaceuticals in wastewater treatment plants. Process Safety and Environmental Protection, 150, 532-556, 2021.

[11]. Anonymous 2021. Overview – Antidepressants, https://www.nhs.uk, Access Date: 15.01.2023, 2021.

[12]. Yüce, H., Ünüvar, S., Antidepresanların Biyoakümülasyonuna Bağlı Ekotoksisite Riski: Sistematik Derleme. Literatür Eczacılık Bilimleri Dergisi, 11(2), 152-158, 2022.

[13]. Choi, J., Zhao, Y., Bediako, J. K., Cho, C., Yun, Y., Estimating environmental fate of tricyclic antidepressants in wastewater treatment plant. Science of The Total Envitonment, 634, 52-58, 2018.

[14]. Yılmaz, C., Sakarya ilinde kanalizasyon sularında ilaç bileşiklerinin araştırılması. Yüksek lisans tezi, Sakarya Üniversitesi Fen Bilimleri Enstitüsü, Sakarya, Türkiye, 2019.

[15]. Pivetta, R. C., Rodrigues-Silva, C., Ribeiro, A. R., Rath, S., Tracking the occurrence of psychotropic pharmaceuticals in Brazilian wastewater treatment plants and surface water, with assessment of environmental risks. Science of the Total Environment, 727, 138661, 2020.

[16]. Gornik, T., Kovacic, A., Heath, E., Hollender, J., Kosjek, T., Biotransformation study of antidepressant sertraline and its removal during biological wastewater treatment. Water Research, 181, 115864, 2020.

[17]. Melchor-Martínez, E. M., Jiménez-Rodríguez, M. G., Martínez-Ruiz, M., Peña-Benavides, S. A., Iqbal, H. M., Parra-Saldívar, R., Sosa-Hernández, J. E., Antidepressants surveillance in wastewater: Overview extraction and detection. Case Studies in Chemical and Environmental Engineering, 3, 100074, 2021.

[18]. Dökmeci, A. H., Bazı farmasötik ilaç kalıntılarının sulardaki toksik etkileri. Doktora tezi, Trakya Üniversitesi Sağlık Bilimleri Enstitüsü, Edirne, Türkiye, 2009.

[19]. Singh, A., Saidulu, D., Gupta, A. K., Kubsad, V., Occurrence and fate of antidepressants in the aquatic environment: Insights into toxicological effects on the aquatic life, analytical methods, and removal techniques. Journal of Environmental Chemical Engineering, 109012, 2022.

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