Humic Substances In Water Behind Taleghan Dam, Iran In 2022

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ABSTRACT
Natural organic matter (NOM) is ubiquitous in water sources, particularly in dam reservoirs. Fulvic acids, humic acids, and humins can act as precursors to trihalomethanes (THMs) and haloacetic acids (HAAs) generated during water disinfection. This study aimed to quantify humic substances in the water behind Taleghan Dam, a vital water source for Tehran, which has experienced declining levels due to climate change. In the summer and autumn of 2022, samples were taken at three stations. Elevated concentrations of humic acid and fulvic acid were observed in summer, peaking at 0.191 mg.L^{-1} and 1.372 mg.L^{-1}, respectively, while the highest concentration of humin (1.382 mg.L^{-1}) was observed in autumn. Total humic substances (THS) peaked in summer (August) before the entry point into the lake, likely due to decreased rainfall and increased bioactivity. Fluctuations in dissolved organic carbon (DOC) concentrations were noted across months and stations, ranging from 5.6 to 190 mg.L^{-1}. The highest DOC concentrations were observed at stations 1 and 2 in October. Specific ultraviolet absorbance (SUVA) values below 2 L.mg^{-1}.m^{-1} indicated the potential for HAA formation. All samples throughout the study exhibited THMFP concentrations surpassing drinking water standards. These findings suggest the potential for disinfection byproduct formation in the water. The study linked variations in humic substances to prevalent soil types, urban expansion, and land use changes along riverbanks. The findings highlight the importance of monitoring water quality to manage the formation and control of THMs in Taleghan Dam.

Keywords: Dam reservoir, Fulvic acid, Humic acid, Humin, NOM, Taleghan Dam.

HIGHLIGHTS

- HPLC-SEC analysis was performed to identify the constituent levels of humic substances.
- The concentration of humic compounds underwent seasonal changes.
- The concentrations of humin surpassed fulvic and humic acids.
- SUVA values were indicative of predominance hydrophilic compounds.
- Humic substances were linked to the region-specific soil types.

1. INTRODUCTION

Water, as a strategic resource both in the contemporary era and throughout history, plays a pivotal role in the natural cycle, the advancement of agricultural endeavors, and the preservation of human health. Surface and groundwater are the primary sources of water supply in both rural and urban areas. To safeguard the health and integrity of these resources, it is imperative to promptly identify the sources of contamination, anticipate the spread of such contaminants, and implement essential measures for their mitigation and prevention (Kundu et al. 2024; Htet et al., 2025).

In recent decades, environmental concerns stemming from organic substances have increased (Rajneesh Kumar et al. 2021; Wu et al. 2023; Violet & Hazarika, 2024). Natural organic matter (NOM), which arises from both allochthonous (terrestrial organic carbon input) and autochthonous (phytoplankton and macrophytes within a water source) origins, is abundant in all water sources (Marais et al. 2017). In drinking water resources, the presence of NOM can pose significant aesthetic and health concerns, necessitating water treatment (Alver et al. 2018). NOMs consist of hydrophobic and hydrophilic fractions. These fractions are not removed during conventional water treatment due to their contrasting chemical properties. Instead, they instigate the formation of byproducts and foster the proliferation of microorganisms within the water distribution network (Riyadh & Peleato 2024). The concentration of these natural organic substances in surface water averages approximately 2.47 $mg.L^{-1}$ (Hang Vo-Minh et al. 2022; Khodabakhshi et al. 2023; Lee & Westerhoff 2006; Kumar et al., 2024). Conventional water treatment and purification techniques are not efficacious in removing these substances, thereby permitting their ingress into water chlorination units and, ultimately, their utilization for potable purposes (Zhang et al. 2015).

Humic substances can be categorized into three primary constituents based on their solubility in acidic or alkaline extracting solutions: humic acids, which are soluble in alkali and insoluble in acid; fulvic acids, which are soluble in both alkali and acid; and humin, which resists extraction with dilute acid and alkali and remains insoluble in such environments (Barloková et al. 2023; Dube et al., 2024). The distinctions among these components stem from factors such as particle size, the structure of humic materials (aromatic and aliphatic degree), elemental ratios, and the number of functional groups (Linnik et al. 2013; Yang et al. 2021).

The present study set out to quantify the levels of humic substances in the water behind Taleghan Dam. The rationale for selecting this surface water source for assessment is multifaceted. According to recent investigations and the latest data on water storage at Taleghan Dam, only 170 million cubic meters of the original 429 million cubic meters of the reservoir have been filled, which can be attributed primarily to lower precipitation levels (Ghahreman & Rahimzadegan 2022; Najafian 2024). The water level behind the dam significantly influences the presence of humic substances within the reservoir. As the lake's water level recedes due to increased consumption or insufficient rainfall, aquatic vegetation along the shoreline proliferates. Subsequently, with the onset of autumn rains and the subsequent rise in lake levels, these plants become submerged, contributing to the increased presence of humic compounds in the water storage reservoir (Hayes & Swift 2020; Lyde et al. 2013; Tursinbayeva et al., 2023). Furthermore, Taleghan is a prominent center for animal husbandry; animal manure could be an additional factor. Additionally, the composition of humic substances in the soil is inherently tied to the soil formation environment. For instance, fully decomposed humic substances are more prevalent in Mollisols, while the humin fraction is commonly found in Vertisols, fulvic acid in Spodosols, and humic acid in Leonardite (Von Wandruszka 2000; Ochilov et al., 2024).

The groundbreaking aspect of this study lies in its meticulous investigation into the diverse types of humic substances present in the water behind Taleghan Dam, unraveling a complex interplay between water dynamics, vegetation patterns, and humic compound concentrations and linking their origins in various soil types to the reservoir's unique composition. By bridging the gap between soil-derived organic matter and water quality in dam reservoirs, this research not only enriches the current understanding of humic compounds but also provides a novel perspective on the ecological intricacies shaping water environments and deepens the understanding of the significance of terrestrial DOM in dam reservoirs.

2. MATERIALS AND METHODS

Study area

Taleghan Dam is located 135 kilometers northwest of Tehran, between the geographical coordinates of 50°37' to 51°10' longitude and 36°5' to 36°25' latitude. It is situated on the Taleghan River within the Sefidrud catchment area. Geologically, Taleghan is part of the Central Alborz region and comprises geological formations from the Precambrian to Quaternary periods, which have been influenced by significant tectonic activity. This earthen dam is constructed with pebbles and a clay core, with a crown length of 1,111 meters and a height of 109 meters from its foundation. The dam has a total volume of 429 million cubic meters, with its primary goals being the improvement of agricultural water supply in the Qazvin plain, supplying part of Tehran’s drinking water, facilitating artificial recharge, and generating 61 gigawatt-hours of hydroelectric power annually (Davani Motlagh et al. 2021; Safarov et al., 2024). According to data from the Taleghan Meteorological Station, the average annual temperature is approximately 11.4°C, and the average annual rainfall in the Taleghan area is 471 mm (Khaleghi et al. 2022; Khayitov et al., 2023). Based on the soil shapefile for Iran (Fig. 1), the soil in the study area is classified as clayey in texture, exhibiting relatively high levels of lime and electrical conductivity (EC), an alkaline pH, and is primarily composed of Vertisols, along with some Spodosols.

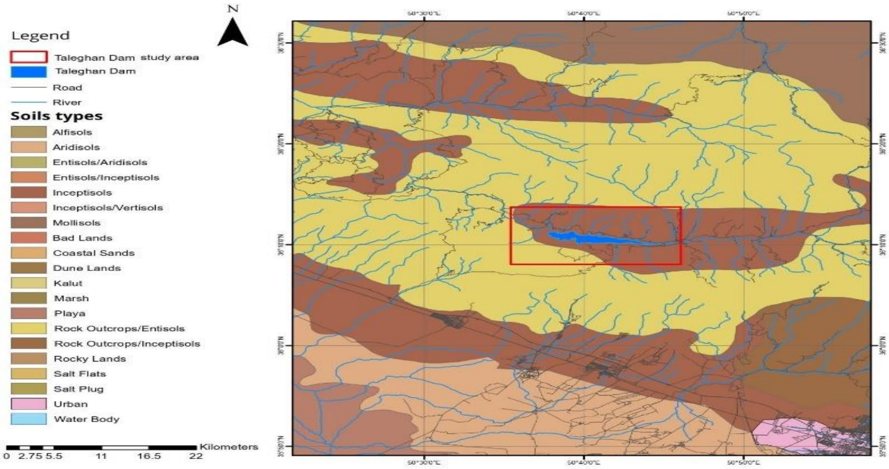

Fig. 1. The soil shapefile for Iran.

Sampling and characterization

Sampling was conducted during two distinct seasons: (a) summer, characterized by reduced water inflow, and (b) autumn, associated with increased precipitation. Water sampling was carried out at three designated stations (Fig. 2): S-1, situated before the entry point into the lake; S-2, positioned in the middle of the lake; and S-3, located near Taleghan Dam. The selection of these stations was based on their accessibility and ability to present a schematic of water quality throughout the dam. Sampling activities were conducted with the requisite permits from the Operation and Maintenance Department of Taleghan Dam and Power Plant. Grab samples were collected instantaneously at specific points within the stream, ensuring uniform flow across the cross-section, approximately 1.5 to 4.5 kilometers downstream from the branching point.

To quantify humic acids, fulvic acids, and humins, high-purity standards of humic acid and fulvic acid with a purity level of 97% were procured from Sigma-Aldrich, while the humin was directly sourced from Merck (Germany). The constituent levels were determined using High-Performance Liquid Chromatography-Size Exclusion Chromatography (HPLC-SEC, Agilent) with a liquid column of tetrahydrofuran and toluene. Concentrations of dissolved organic carbon (DOC) were measured using a TOC analyzer (Shimadzu, Japan), and the values of UV absorbance at 254 nm (UV_{254}) were determined using a spectrophotometer (SQ-4802, Shanghai, China). Specific UV absorbance (SUVA), defined as the ratio of absorbance at 254 nm/m to the concentration of DOC ($mg.L^{-1}$), and the trihalomethane formation potential (THMFP) were also calculated (Canale et al. 1997).

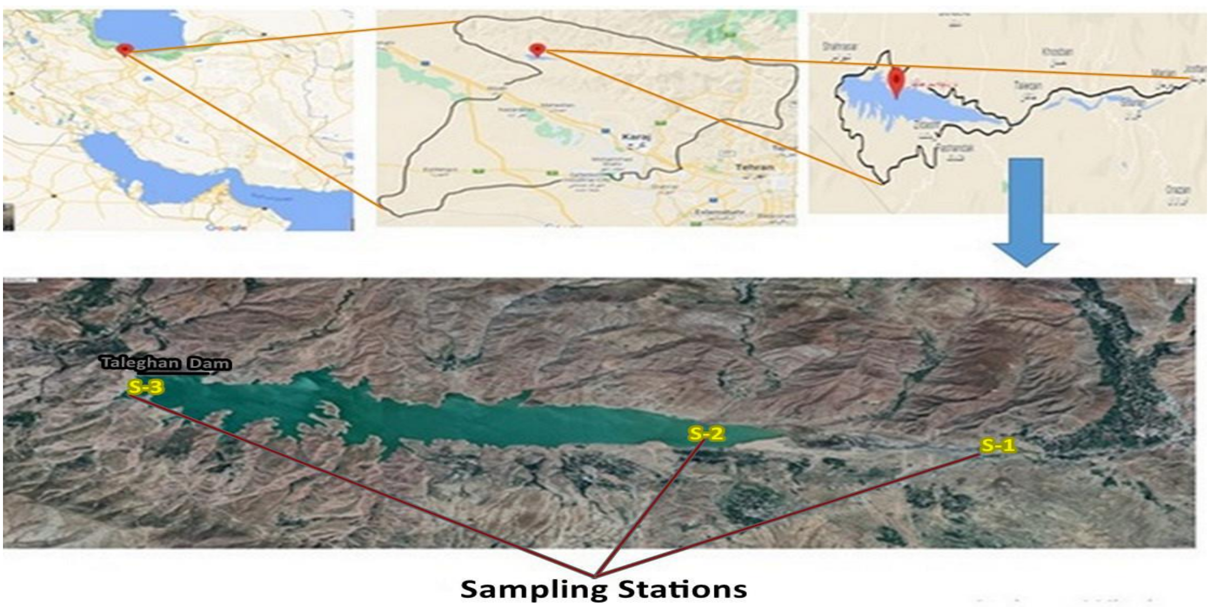

Fig. 2. A view of the sampling stations in the Taleghan River and Lake.

3. RESULTS AND DISCUSSION

The quality of water samples obtained from the Taleghan River and Lake are presented in Table 1.

Table 1. The values of the determined parameters of water at the sampling points

No. samp	p	No. of station	Samplir month	Humic acid (mg.L^{-1})	Fulvic acid (mg.L^{-1})	Humi (mg.L	THS (mg.L^{-1}	DOC (mg.L^{-}	UV$_{25}$ (m^{-1})	SUVA (L.mg^{-1}.m^{-1})	THMF (µg.L^{-1})
1	8.	1	Novemb r	0.08	0.367	1.382	1.829	5.6	9	1.61	375.84
2	8.	3	Septemb r	0.133	1.021	1.152	2.306	15.6	10	0.64	1349.8
3	8.	2	August	0.191	1.256	1.160	2.607	42.4	9	0.21	4701.41
4	8.	3	Novemb r	0	0.234	0.372	0.606	34.4	9.5	0.27	3621.6
5	8.	1	August	0.169	1.372	1.376	2.917	24	6	0.25	2310.8
6	8.	1	Septemb r	0.115	1.014	1.125	2.254	19.2	8	0.41	1749.1
7	8.	3	October	0.086	0.507	1.220	1.813	11.6	12	1.03	932.651
8	8.	2	Septemb r	0.123	0.936	0.974	2.033	6.8	10	1.47	478.90
9	8.	3	August	0.153	1.160	1.162	2.475	8	8.5	1.06	586.58
10	8.	2	October	0.085	0.554	0.691	1.33	106.8	11.5	0.1	14891.
11	8.	1	October	0.088	0.595	0.710	1.393	190	11	0.057	30560.

Here, the main humic substances in the water behind Taleghan Dam were assessed during 2022. As depicted in Table 1, the concentrations of humin surpassed those of the other two constituents, i.e., fulvic and humic acids. From a seasonal perspective, the highest concentrations of humic acid and fulvic acid were reported in summer, reaching 0.191 and 1.372 mg.L^{-1}, respectively, while the highest concentration of humin (1.382 mg.L^{-1}) was observed in autumn. Overall, the highest concentration of total humic substances (THS) was observed in summer (August) before the entry point into the lake (S-1). As water temperature rises, microbial activity increases and hydrophilic compounds form more readily (Lumsdon et al. 2005). Additionally, during the dry season, there is an increase in the photo-degradation rate of colored dissolved organic matter (DOM), especially aromatic organic compounds (Awad et al. 2017). Higher concentrations in summer could primarily be attributed to reduced rainfall during warm seasons in the region. Additionally, Taleghan is a hub of animal husbandry, and the presence of animal manure can also contribute to the increased concentrations of these compounds in water.

When raw (untreated) water is high in hydrophobic, aromatic, and humic compounds, THMs tend to form more readily compared to when treated water has non-aromatic, hydrophilic compounds (Awad et al. 2016).

In contrast, Zhao et al. (2006) found that low molecular weight DOM compounds were the major THM precursors in river water. According to the literature, the composition of DOM in a watershed is largely determined by the hydrologic connectivity of different landscapes upstream of the receiving waters (Johnston et al. 2020; Lynch et al. 2019). In a study by Chen et al. (2016) tracking monthly changes in the composition of DOM in a recently constructed reservoir, the results indicated that during the dry season, the smaller molecular fractions of DOM became more abundant, presumably due to photo and bio-degradation in the reservoir. It was also found that storms mobilized a large amount of highly aromatic soil-derived DOM to the reservoirs. In addition, Volk et al.'s (2005) observations of fluctuations in DOM in rivers showed changes not only in quantity but also in composition following precipitation, suggesting that runoff filtered down humic substances from the upper soil layer, causing these fluctuations.

The observed variations in the concentration of humic substances in the study were linked to the soil types prevalent in the region. The rapid expansion of urban and rural areas along riverbanks, coupled with population growth, has resulted in extensive encroachments on riverbed boundaries and the physical integrity of waterways. There have been such encroachments on the Taleghan River in particular, which has made it an important river in the country due to its proximity to Alborz Province, the third metropolitan area in Iran; the construction of the Taleghan Dam and its vital role as a source of irrigation for crops along the Qazvin plain. The construction of this dam, accompanied by alterations in the geological structure, land use patterns, and newly developed roads, has led to modifications in specific river segments, which could be correlated with variations in humic substances. A study by Liu et al. (2019), highlighted that land use changes, especially urbanization and agricultural activities, significantly influence the composition and concentration of humic substances in water bodies.

In surface waters such as rivers and lakes, the composition of NOM may be affected by hydrology and soil (Ramavandi et al. 2015). Literature reveals that, in general, soils contain higher concentrations of humin and humic acids (HAs). In contrast, fulvic acid (FA) is a water-soluble compound that occurs at relatively high concentrations both in soil and water (Pettit 2004). In mineral soils, humin materials are strongly associated with soil inorganic colloids, where hydrophobic bonding plays a major role in adsorption (Hayes et al. 2017). Humic substances in soil contain a higher percentage of ring compounds (aromatic) than humic substances in water (Pettit 2004).

In light of the information presented, a correlation can be established between the soil type and the values of particular humic substances within the study region. According to the soil shapefile for Iran (Fig. 1), the soil type in the study area is categorized as follows: clayey in texture, with relatively high lime and EC, as well as alkaline pH (predisposed to THMs and HAAs formation), Vertisols (prone to the presence of high humin), and more or less Spodosols (prone to the presence of high fulvic acid).

To quantify DOM in water systems, DOC is the most commonly used parameter (Zhao et al. 2018). Considering the DOC concentrations, we noted that the values in August, September, October, and November in all three stations varied considerably (5.6-190 $mg.L^{-1}$**)** while humic substances were more stable. Furthermore, a range of DOC from 5.6 to 190 $mg.L^{-1}$ created a THMFP of 375.8 to 30560.5 $\mu g.L^{-1}$. Notably, the THMFP concentrations of all samples throughout the study were substantially higher than the 100 $\mu g.L^{-1}$ maximum contaminant level for THMs in drinking water (Fooladvand et al. 2011). However, these concentrations are not directly comparable to treated water THM concentrations, which undergo coagulation and filtration before disinfection and are exposed to different temperatures and chlorine levels.

The highest concentrations of DOC were observed at stations 1 and 2, respectively, in October. Fluctuations in DOC can be attributed to the turbulent flow at the river intake, which diffused and dissolved sediments at the bottom of the canal. The average pH value of the water was 8.25±0.094, which could facilitate the dissolution of DOC (Libecki & Dziejowski 2008). High DOC concentrations in treated water can affect its quality and increase coagulant demand in water treatment plants (WTPs), raising the possibility of THM formation (Matilainen et al. 2010). Wang et al. (2012) concluded that specific factors influenced DOC in river systems. Thus, DOC concentrations in rivers varied greatly between the mainstream and tributaries due to the diverse landscapes and human activities over a large area. Additionally, Nelson et al. (1992) found that soil types influence DOC concentrations within a stream based on their adsorption capacities. Clay-rich surface horizons typically exhibit stronger adsorption characteristics than coarse-textured soils (Awad et al. 2016). Results of a study by Chow et al. (2017) also demonstrated that climatic and hydrological factors are the dominant drivers for stream DOC dynamics.

UV_{254} is more indicative of aromatic organic content, which forms disinfection byproducts (DBPs) more readily when combined with chlorine. The amount of UV absorbance in water is a good indication of the bulk concentration of precursors, but a parameter called specific UV absorbance (SUVA) is better for detecting the nature and reactivity of precursors (Alver et al. 2018). SUVA values were used to determine the hydrophobicity of DOM, which is a useful indicator of the DBP formation potential of the water. Microbial decomposition of DOM can enhance SUVA values, and therefore, higher SUVA values may reflect higher humification, a more hydrophobic nature, or lower biodegradability of DOM (Hur 2011). A SUVA value less than 2 indicates a predominance of non-humic substances with lower hydrophobicity. A SUVA value between 2 and 4 signifies a mixture of hydrophilic and hydrophobic components, and a value exceeding 4 implies a preponderance of hydrophobic organic components, primarily composed of humic components (Marais et al. 2017; Tungsudjawong et al. 2017). As illustrated in Table 1, SUVA values of all water samples varied from 0.057 to 1.61 $L.mg^{-1}.m^{-1}$. The highest SUVA level ((1.61 $L.mg^{-1}.m^{-1}$) indicating the predominance of non-humic substances with lower hydrophobicity) occurred in November before the entry point into the lake for the period of investigation. The literature indicates that high SUVA values are indicative of humic substances, whereas low SUVA values indicate organic matter that can be measured by DOC and total organic carbon (TOC) but does not affect color or absorb UV light (Moodley et al. 2017). Compounds with high hydrophobicity tend to promote THMs formation, whereas hydrophilic compounds (SUVA < 2) prefer to form HAAs during chlorination (Bond et al. 2009).

In future studies, the persistence of THM precursors should be considered to determine how far these compounds will travel before decay, which will determine whether they reach drinking water. If the degradation of THM precursors is rapid, only sources close to drinking water intakes need to be monitored. If degradation is slow, even distant sources could contribute to THM concentrations in drinking water.

4. CONCLUSIONS

Addressing the shortage of clean drinking water requires scrutiny of water reservoirs behind dams. NOM, including fulvic acids, humic acids, and humins, constitutes a significant category of contaminants in these reservoirs, prevalent in all water sources. The results of this study highlighted that humin concentrations surpassed those of fulvic and humic acids, with the highest levels observed in autumn. Notably, the summer months exhibited elevated concentrations of humic and fulvic acids, attributed to increased microbial activity and reduced rainfall, potentially influenced by the local animal husbandry practices. Moreover, the research shed light on the intricate relationship between the presence of humic substances and the specific soil types in the region, emphasizing the impact of urban expansion and land use changes on water quality. This is particularly relevant given the potential changes in water balance and quality due to land use changes in the Taleghan catchment area. The findings underscored the significance of considering soil composition, hydrology, and human activities in understanding the dynamics of dissolved organic matter (DOM) and its implications for disinfection byproduct formation.

The study's results also indicated that DOC concentrations varied significantly across different months and stations, influencing trihalomethane formation potential (THMFP). Furthermore, SUVA values less than 2 revealed a predominance of non-humic substances with lower hydrophobicity.

Since the presence of these compounds at the source has been confirmed, future research will continue to monitor the changes in their concentration from the source to the treatment plant. This will provide a clearer understanding of how these compounds behave and their fate over time. If their concentrations exceed standard limits, regional water authorities should be promptly informed to implement measures to reduce the entry of these compounds into the treatment plant. Overall, failure to undertake suitable measures could lead to an escalation of critical humic components in water storage sources, posing a significant threat to the Taleghan River and Dam. This study contributes to the broader understanding of humic substances in water environments, emphasizing the need for integrated approaches that consider the interconnectivity of soil, water, and anthropogenic factors in managing water quality and treatment processes effectively.

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REFERENCES

1. alver, A., Baştürk, E., Kiliç, A. 2018 Disinfection By-Products Formation Potential Along The Melendiz River, Turkey; Associated Water Quality Parameters And Non-Linear Prediction Model. International Journal Of Environmental Research, 12, 909-919. Https://Doi.Org/10.1007/S41742-018-0145-4.

2. Awad, J., Van Leeuwen, J., Chow, C., Drikas, M., Smernik, R.J., Chittleborough, D.J., Bestland, E. 2016 Characterization Of Dissolved Organic Matter For Prediction Of Trihalomethane Formation Potential In Surface And Sub-Surface Waters. Journal Of Hazardous Materials, 308, 430-439. Https://Doi.Org/10.1016/J.Jhazmat.2016.01.030.
3. Awad, J., Van Leeuwen, J., Chow, C.W., Smernik, R.J., Anderson, S.J., Cox, J.W. 2017 Seasonal Variation In The Nature Of Dom In A River And Drinking Water Reservoir Of A Closed Catchment. Environmental Pollution, 220, 788-796. Https://Doi.Org/10.1016/J.Envpol.2016.10.054.
4. Barloková, D., Ilavský, J., Sedláková, J., Matis, A. 2023 Removal Of Humic Substances From Water With Granular Activated Carbons. Engineering Proceedings, 57, 22. Https://Doi.Org/10.3390/Engproc2023057022.
5. Bond, T., Henriet, O., Goslan, E., Parsons, S., Jefferson, B. 2009 Disinfection Byproduct Formation And Fractionation Behavior Of Natural Organic Matter Surrogates. Environmental Science & Technology, 43, 5982-5989. Https://Doi.Org/10.1021/Es900686p.
6. Canale, R.P., Chapra, S.C., Amy, G.L., Edwards, M.A. 1997 Trihalomethane Precursor Model For Lake Youngs, Washington. Journal Of Water Resources Planning And Management, 123, 259-265. Https://Doi.Org/10.1061/(Asce)0733-9496(1997)123:5(259).
7. Chen, M., He, W., Choi, I., Hur, J. 2016 Tracking The Monthly Changes Of Dissolved Organic Matter Composition In A Newly Constructed Reservoir And Its Tributaries During The Initial Impounding Period. Environmental Science And Pollution Research, 23, 1274-1283. Https://Doi.Org/10.1007/S11356-015-5350-5.
8. Chow, M.F., Lai, C.-C., Kuo, H.-Y., Lin, C.-H., Chen, T.-Y., Shiah, F.-K. 2017 Long Term Trends And Dynamics Of Dissolved Organic Carbon (Doc) In A Subtropical Reservoir Basin. Water, 9, 545. Https://Doi.Org/10.3390/W9070545.
9. Davani Motlagh, A., Sadeghian, M., Javid, A., Asgari, M. 2021 Optimization Of Dam Reservoir Operation Using Grey Wolf Optimization And Genetic Algorithms (A Case Study Of Taleghan Dam). International Journal Of Engineering, 34, 1644-1652. Https://Doi.Org/10.5829/Ije.2021.34.07a.09.
10. Dube A., Jaybhaye M.D., More P., Jaybhaye S.M. (2024), Study Of Variation In Physiochemical Properties Of A Worm Gearbox Lubricant By Blending Castor Oil In The Base Lubricant, Journal Of Materials And Engineering, 2(4), 273-278, 10.61552/Jme.2024.04.005
11. Fooladvand, M., Ramavandi, B., Zandi, K., Ardestani, M. 2011 Investigation Of Trihalomethanes Formation Potential In Karoon River Water, Iran. Environmental Monitoring And Assessment, 178, 63-71. Https://Doi.Org/10.1007/S10661-010-1672-4.
12. Ghahreman, R., Rahimzadegan, M. 2022 Calculating Net Radiation Of Freshwater Reservoir To Estimate Spatial Distribution Of Evaporation Using Satellite Images. Journal Of Hydrology, 605, 127392. Https://Doi.Org/10.1016/J.Jhydrol.2021.127392.
13. Hang Vo-Minh, N., Jin, H., Hyun-Sang, S. 2022 Humic Acids And Fulvic Acids: Characteristics, Sorption Of Hydrophobic Organic Contaminants, And Formation Of Disinfection By-Products During Chlorination. In: Abdelhadi, M. (Ed.) Humus And Humic Substances. Rijeka: Intechopen. Http://Dx.Doi.Org/10.5772/Intechopen.105518.
14. Hayes, M.H., Mylotte, R., Swift, R.S. 2017 Humin: Its Composition And Importance In Soil Organic Matter. Advances In Agronomy, 143, 47-138. Https://Doi.Org/10.1016/Bs.Agron.2017.01.001.
15. Hayes, M.H., Swift, R.S. 2020 Vindication Of Humic Substances As A Key Component Of Organic Matter In Soil And Water. Advances In Agronomy, 163, 1-37. Https://Doi.Org/10.1016/Bs.Agron.2020.05.001.
16. Htet A., Liana S., Aung T., Bhaumik A., Giri O. (2025), From Waste To Wealth: Circular Economy Approaches In Facade Engineering, Journal Of Engineering, Management And Information Technology, 3(1), 29-38, 10.61552/Jemit.2025.01.004
17. Hur, J. 2011 Microbial Changes In Selected Operational Descriptors Of Dissolved Organic Matters From Various Sources In A Watershed. Water, Air, & Soil Pollution, 215, 465-476. Https://Doi.Org/10.1007/S11270-010-0491-0.
18. Johnston, S.E., Striegl, R.G., Bogard, M.J., Dornblaser, M.M., Butman, D.E., Kellerman, A.M., Wickland, K.P., Podgorski, D.C., Spencer, R.G. 2020 Hydrologic Connectivity Determines Dissolved Organic Matter Biogeochemistry In Northern High-Latitude Lakes. Limnology And Oceanography, 65, 1764-1780. Https://Doi.Org/10.1002/Lno.11417.
19. Khaleghi, S., Hasan Sadogh, S., Khodayari, M. 2022 Assessment Of Morphological Mhanges Of Taleghan River In Upstream Of Taleghan Dam. Sustainable Earth Review, 2, 38-45. Https://Doi.Org/10.52547/Sustainearth.1.1.38.
20. Khayitov, O., Saidova, L., Galiev, S., Umirzokov, A., & Mahkamov, M. (2023). Interrelation Of Performance Indicators Of Technological Transport With Mining Conditions Of A Quarry. News Of National Academy Of Sciences Of The Republic Of Kazakhstan, 226-239.
21. Khodabakhshi, A., Riahi Farssani, A., Sedehi, M., Sadeghi, M. 2023 Removal Of Natural Organic Matter (Nom) From Aqueous Solutions By Multi-Walled Carbon Nanotube Modification With Magnetic Fe3o4 Nanoparticles. International Journal Of Chemical Engineering, 2023, 5936331. Https://Doi.Org/10.1155/2023/5936331.
22. Kumar, S., Dubey, M. K., Mehdi, H., Kalla, S. K., & Krishanan, R. P. (2024). A Study Of Industry 4.0 For Circular Economy And Sustainable Development Goals In The Environment Of Vuca, Journal Of Innovations In Business And Industry, 2(2), 95-102, 10.61552/Jibi.2024.02.005

23. Kundu, D., Dutta, D., Joseph, A., Jana, A., Samanta, P., Bhakta, J.N., Alreshidi, M.A. 2024 Safeguarding Drinking Water: A Brief Insight On Characteristics, Treatments And Risk Assessment Of Contamination. Environmental Monitoring And Assessment, 196, 180. Https://Doi.Org/10.1007/S10661-024-12311-Z.
24. Lee, W., Westerhoff, P. 2006 Dissolved Organic Nitrogen Removal During Water Treatment By Aluminum Sulfate And Cationic Polymer Coagulation. Water Research, 40, 3767-3774. Https://Doi.Org/10.1016/J.Watres.2006.08.008.
25. Libecki, B., Dziejowski, J. 2008 Optimization Of Humic Acids Coagulation With Aluminum And Iron (Iii) Salts. Polish Journal Of Environmental Studies, 17, 397-403. Https://Www.Pjoes.Com/Pdf-88121-21979?Filename=Optimization%20of%20humic.Pdf.
26. Linnik, P., Ivanechko, Y.S., Linnik, R., Zhezherya, V. 2013 Humic Substances In Surface Waters Of The Ukraine. Russian Journal Of General Chemistry, 83, 2715-2730. Https://Doi.Org/10.1134/S1070363213130185.
27. Liu, Q., Jiang, Y., Tian, Y., Hou, Z., He, K., Fu, L., Xu, H. 2019 Impact Of Land Use On The Dom Composition In Different Seasons In A Subtropical River Flowing Through A Region Undergoing Rapid Urbanization. Journal Of Cleaner Production, 212, 1224-1231. Https://Doi.Org/10.1016/J.Jclepro.2018.12.030.
28. Lumsdon, D.G., Stutter, M.I., Cooper, R.J., Manson, J.R. 2005 Model Assessment Of Biogeochemical Controls On Dissolved Organic Carbon Partitioning In An Acid Organic Soil. Environmental Science & Technology, 39, 8057-8063. Https://Doi.Org/10.1021/Es050266b.
29. Lyde, T.A., Daoud, A., Dieudonné, Z.N., Ousmane, B., Moctar, B.L. 2013 Eutrophication, Sediment Phosphorus Fractionation And Short-Term Mobility Study In The Surface And Under Profile Sediment Of A Water Dam. (Okpara Dam, Benin, West Africa). Journal Of Applied Sciences And Environmental Management, 17, 517-526. Http://Dx.Doi.Org/10.4314/Jasem.V17i4.9.
30. Lynch, L.M., Sutfin, N.A., Fegel, T.S., Boot, C.M., Covino, T.P., Wallenstein, M.D. 2019 River Channel Connectivity Shifts Metabolite Composition And Dissolved Organic Matter Chemistry. Nature Communications, 10, 459. Https://Doi.Org/10.1038/S41467-019-08406-8.
31. Marais, S.S., Ncube, E.J., Msagati, T.A.M., Mamba, B.B., Nkambule, T.I. 2017 Investigation Of Natural Organic Matter (Nom) Character And Its Removal In A Chlorinated And Chloraminated System At Rand Water, South Africa. Water Supply, 17, 1287-1297. Https://Doi.Org/10.2166/Ws.2017.028.
32. Matilainen, A., Vepsäläinen, M., Sillanpää, M. 2010 Natural Organic Matter Removal By Coagulation During Drinking Water Treatment: A Review. Advances In Colloid And Interface Science, 159, 189-197. Https://Doi.Org/10.1016/J.Cis.2010.06.007.
33. Moodley, K., Sobantu, P., Gericke, G., Chetty, D., Pienaar, D. 2017 Comparison Of Uv And Els Detectors In Hspec Analysis Of Natural Organic Matter In Dam Water. Water Sa, 43, 520-528. Https://Doi.Org/10.4314/Wsa.V43i3.17.
34. Najafian, D. 2024 (Ceo Of The Province’s Regional Water Company), Water Shortage Warning In Tehran. Energy Press. Available At: Https://Energypress.Ir/En/Water-Shortage-Warning-In-Tehran/ [Accessed: 7 April 2024].
35. Nelson, P., Baldock, J., Oades, J. 1992 Concentration And Composition Of Dissolved Organic Carbon In Streams In Relation To Catchment Soil Properties. Biogeochemistry, 19, 27-50. Https://Doi.Org/10.1007/Bf00000573.
36. Ochilov, S. A., Makhmudov, D. R., Nizamova, A. T., Norinov, S. S., & Umirzokov, A. A. (2024). Methods For Calculating The Parameters Of Drilling And Blasting Operations Based On The Primary Determination Of The Zones Of Destruction Of The Rock Mass. In E3s Web Of Conferences (Vol. 491, P. 02014). Edp Sciences.
37. Pettit, R.E. 2004 Organic Matter, Humus, Humate, Humic Acid, Fulvic Acid And Humin: Their Importance In Soil Fertility And Plant Health. Cti Research, 10, 1-17. Https://Humates.Com/Wp-Content/Uploads/2020/04/Organicmatterpettit.Pdf.
38. Rajneesh Kumar, G., Dimuth, N., Shobha, M., Amarendra, S., Islamuddin, Nandkishor, M. 2021 Humic Substances: Its Toxicology, Chemistry And Biology Associated With Soil, Plants And Environment. In: Abdelhadi, M. (Ed.) Humic Substances. Rijeka: Intechopen. Http://Dx.Doi.Org/10.5772/Intechopen.98518.
39. Ramavandi, B., Farjadfard, S., Ardjmand, M., Dobaradaran, S. 2015 Effect Of Water Quality And Operational Parameters On Trihalomethanes Formation Potential In Dez River Water, Iran. Water Resources And Industry, 11, 1-12. Https://Doi.Org/10.1016/J.Wri.2015.03.002.
40. Riyadh, A., Peleato, N.M. 2024 Natural Organic Matter Character In Drinking Water Distribution Systems: A Review Of Impacts On Water Quality And Characterization Techniques. Water, 16. Https://Doi.Org/10.3390/W16030446.
41. Safarov, B., Janzakov, B., Bakayev, Z., Yu, J., Hassan, T. H., Beknazarov, B., ... & Mansurova, N. (2024). The Impact Of Cultural Heritage On Economic Growth In The Example Of Museum Development In Uzbekistan. In International Conference On Computational Science And Its Applications (Pp. 334-343). Cham: Springer Nature Switzerland.
42. Tungsudjawong, K., Leungprasert, S., Peansawang, P. 2017 Investigation Of Humic Acids Concentration In Different Seasons In A Raw Water Canal, Bangkok, Thailand. Water Supply, 18, 1727-1738. Https://Doi.Org/10.2166/Ws.2017.235.
43. Tursinbayeva, G., Saparov, A., Turekeeva, A., Atanazarov, K., Matrasulov, G., Sindarov, S. E., ... & Mardanova, A. T. (2024). Leaf Structure Of Species Of The Brassicaceae Burnett Family In Southwestern Kyzylkum, Uzbekistan. Caspian Journal Of Environmental Sciences, 22(2), 459-475.
44. Violet, N., & Hazarika, A. (2024). The Impact Of Financial Inclusion On Economic Growth In Uganda: A Case Study Of Selected Districts In Central Uganda, Journal Of Engineering, Management And Information Technology, 2(1), Pages 23-34, 10.61552/Jemit.2024.01.004

45. Volk, C., Kaplan, L.A., Robinson, J., Johnson, B., Wood, L., Zhu, H.W., Lechevallier, M. 2005 Fluctuations Of Dissolved Organic Matter In River Used For Drinking Water And Impacts On Conventional Treatment Plant Performance. Environmental Science & Technology, 39, 4258-4264. Https://Doi.Org/10.1021/Es040480k.
46. Von Wandruszka, R. 2000 Humic Acids: Their Detergent Qualities And Potential Uses In Pollution Remediation. Geochemical Transactions, 1, 1-6. Https://Doi.Org/10.1186/1467-4866-1-10.
47. Wang, X., Ma, H., Li, R., Song, Z., Wu, J. 2012 Seasonal Fluxes And Source Variation Of Organic Carbon Transported By Two Major Chinese Rivers: The Yellow River And Changjiang (Yangtze) River. Global Biogeochemical Cycles, 26. Https://Doi.Org/10.1029/2011gb004130.
48. Wu, Y., Zhang, X., Hao, R., Zhou, Y., Qiu, G., Hu, R., Song, Y. 2023 Rethinking Terrestrial Dissolved Organic Matter In Dam Reservoirs Before Mixing: Linking Photodegradation And Biodegradation And The Phenanthrene Binding Behavior. Science Of The Total Environment, 904, 166653. Https://Doi.Org/10.1016/J.Scitotenv.2023.166653.
49. Yang, F., Tang, C., Antonietti, M. 2021 Natural And Artificial Humic Substances To Manage Minerals, Ions, Water, And Soil Microorganisms. Chemical Society Reviews, 50, 6221-6239. Https://Doi.Org/10.1039/D0cs01363c.
50. Zhang, Y., Zhao, X., Zhang, X., Peng, S. 2015 A Review Of Different Drinking Water Treatments For Natural Organic Matter Removal. Water Supply, 15, 442-455. Https://Doi.Org/10.2166/Ws.2015.011.
51. Zhao, C., Wang, Z., Wang, C., Li, X., Wang, C.-C. 2018 Photocatalytic Degradation Of Dom In Urban Stormwater Runoff With Tio2 Nanoparticles Under Uv Light Irradiation: Eem-Parafac Analysis And Influence Of Co-Existing Inorganic Ions. Environmental Pollution, 243, 177-188. Https://Doi.Org/10.1016/J.Envpol.2018.08.062.
52. Zhao, Z.-Y., Gu, J.-D., Fan, X.-J., Li, H.-B. 2006 Molecular size distribution of dissolved organic matter in water of the Pearl River and trihalomethane formation characteristics with chlorine and chlorine dioxide treatments. Journal of hazardous materials, 134, 60-66. https://doi.org/10.1016/j.jhazmat.2005.10.032.