

Sustainable Utilization of Olive Mill Wastewater in the Construction Materials: Opportunities and Applications

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ABSTRACT

Olive mill wastewater (OMW) constitutes a noteworthy contributor to environmental contamination. Specifically, it poses a significant environmental challenge for countries that are major producers of olive oil and face water scarcity issues. This review examines the potential of OMW as a partial substitute for freshwater in construction materials and evaluates its effects on the resulting material properties. Studies have investigated OMW at mixing-water replacement levels including 7.5% and 40%. In selected concrete mixtures, 28-day compressive strength increased by up to 38%, while a separate study reported slump increases of up to 430% under different mixture conditions. These results do not establish a universal optimal replacement range. The observed increase in workability suggests a possible effect of OMW constituents on the fresh mixture, but a plasticizing mechanism has not been directly demonstrated. According to ASTM requirements, the properties of the mixed water were assessed, and a 12% OMWW replacement level was identified as the maximum ratio that remained within the specified ASTM limits. Similarly, the incorporation of OMW in bricks can lead to **improved thermal insulation and up to 30% energy savings during firing**. Utilizing OMW in the construction industry not only prevents the adverse effects linked to its disposal but also diminishes the usage of freshwater, especially in nations grappling with water scarcity problems.

1. Introduction

Solid and liquid wastes pose significant threats to the environment. One sector that can benefit from the utilization of waste materials is the construction industry, which is important in both developed and developing nations (Świerczek et al., 2018). The construction sector can utilize these waste materials to effectively eliminate them and minimize the depletion of natural resources required for the production of building materials (Abdulwahid et al., 2023). For example, bricks (Ademati et al., 2022; Akinwande et al., 2023a, 2023b; Barnabas et al., 2023; Zalyhina et al., 2022, 2024), concrete (Olukayode et al., 2023; Yagubkin et al., 2024), gypsum, anhydrite, and their binders (Wang et al., 2024a, b; Kamarou et al., 2023, 2024, 2025; Liu et al., 2024; Romanovski et al., 2024), wastes in pavements (Burduladze et al., 2024), pigments (Zalyhina et al., 2021), composites (Akinwande et al., 2022, 2024), etc. The construction sector is one that requires an abundance of water for

producing various building materials, such as concrete and bricks. Water is regarded as one of the components that construction materials require (Farid et al., 2019). The construction sector ranks as the second most significant user of freshwater globally, coming in right after agricultural consumption (Agwe et al., 2022).

For instance, the manufacturing of concrete presently uses over 10% of the water used in industrial processes worldwide (Carbon cure, 2025). It is anticipated that 75% of the water required to produce concrete in 2050 will come from areas predicted to face water scarcity (Miller et al., 2018). The global concrete industry consumes more than one trillion gallons of water annually, excluding wash water and curing water (Meyer, 2004). Insufficient water supply leads to less water for distribution due to high usage in concrete manufacturing (Hamada et al., 2023). Additionally, the brick industry uses substantial amounts of water in its production (Skouteris et al., 2018). Countless gallons of fresh water are used in the production of fired clay bricks (Ghafoor et al.,

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2022).

Water is the most widely utilized substance globally, with concrete following closely behind as the second most consumed material. This often leads to a substantial increase in the demand for water resources (Atakan et al., 2016). A viable approach to sustainability in construction is using recycled wastewater, which conserves resources, protects the environment, reduces costs, and promotes sustainable practices (Maddikeari et al., 2024). Some studies have found that utilizing wastewater in the production of concrete and for the purpose of curing could potentially alleviate water scarcity to a certain extent (Varshney et al., 2021; Micheal and Salam, 2024). Furthermore, a large amount of wastewater can be repurposed for brick production, which not only helps conserve clean water but also supports the goals of a circular economy (Ghafoor et al., 2022). Recycled water is now being recognized as an innovative solution within the construction industry to combat water scarcity and encourage sustainable methods (Chen et al., 2024).

Wastewater from olive oil mills, known as OMW, is a by-product produced by the olive oil industry. The presence of elevated levels of organic compounds, predominantly phenols, within it gives rise to ecological concerns, including soil contamination and water pollution, thereby posing environmental challenges for the ecosystem (Aydi et al., 2022; Issaoui et al., 2021; Aydi et al., 2015; Azzam and Hazaimah, 2021). Immediate action is needed to process this wastewater to reduce environmental harm, especially in olive-producing countries.

2. Importance and novelty of study

The increasing generation of olive mill wastewater (OMW) and growing water scarcity in olive-producing regions highlight the need for sustainable strategies that can reduce both wastewater pollution and freshwater consumption. One promising approach is the valorization of OMW in construction materials as a partial substitute for freshwater. This review evaluates the reported benefits, limitations, and sustainability implications of using OMW in concrete, bricks, and other construction materials. Despite growing interest, existing studies remain limited and fragmented. Therefore, the novelty of this review lies in consolidating the available evidence, critically comparing reported findings, identifying key technical and environmental challenges, and highlighting research gaps. By viewing OMW as a potential resource rather than merely a waste, this study supports circular-economy practices and encourages further research into its safe and sustainable use in the construction sector.

Literature search and selection. This article is a narrative review. Relevant publications were identified through searches of Scopus database. Search terms combined ("olive mill wastewater" OR "olive oil mill wastewater" OR OMW OR OMWW OR zibar) AND (concrete OR mortar OR cement OR brick OR ceramic OR "road base" OR pavement OR "soil stabilization"). The reference lists of relevant studies were also examined. Studies reporting the use of liquid OMW or another clearly identified olive-processing effluent in construction materials were considered for the main comparison; studies on pomace and sludge were identified separately. Because wastewater composition, dosage definitions, materials, and testing conditions differ across studies, the results are compared qualitatively rather than pooled into a universal optimum percentage.

3. Olive mill wastewater: generation and properties relevant to construction

The production of olive oil plays a crucial role in the economies of the countries that produce it, particularly in the Mediterranean region (Dahdouh et al., 2023; Muezzinoglu, 2023). Globally, the production of olive oil amounts to slightly more than 3 million tons. On average, Spain contributes around 1.4 million tons to this total according to (Spanish Olive Oil, 2025). Fig. 1 shows the olive oil production by country in the world according to (Olive Oil Production by Country, 2025). The

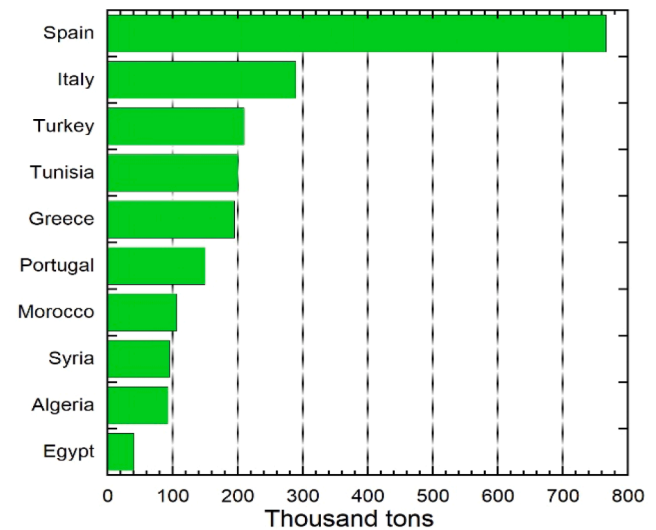


Fig. 1. The global production of olive oil in ton across different countries in the world, 2024 (data from Olive Oil Production by Country, 2025).

production volumes reported in these data are slightly lower but still reflect the large scale of production and Spain's leading position in global olive oil production.

The geographical concentration of olive oil production makes local collection and transport relevant to the feasibility of using OMW in nearby concrete or ceramic plants. However, production volumes in Fig. 1 do not indicate how much wastewater is available for construction use; this depends on the extraction process and wastewater management at individual mills.

Globally, the olive oil industry generates approximately 30 million m³ of OMW and around 20 million tons of solid waste (pomace) annually (Galanakis and Olive, 2017; Font et al., 2020; Khair and Abu-Rumman, 2020; López-García et al., 2021; Rocha et al., 2024; Díaz-García et al., 2017). Fig. 2 shows a typical olive oil production process. The relative quantities of oil, pomace, and liquid wastewater depend on the extraction system; the material balance reported by (Batuecas et al., 2019) should therefore be interpreted for its specific process rather than as a universal mill output.

A medium-sized olive mill processes 10–20 tonnes of olives daily, generating 0.5–1.5 m³ of wastewater per tonne. Approximately 20 kg of oil is obtained from 100 kg of olives, while residue quantities vary with the extraction method (Soares et al., 2026). In turn, wastewater contains 4–16% organic matter, 0.4–2.5% mineral substances, 83–94% water (Karahar Ozgün et al., 2015; Davies et al., 2004).

Olive oil extraction systems produce OMW, also referred to as "Zibar" locally (Alkhalidi et al., 2023). OMW is dark-colored (Solomakou and Goula, 2021), has a low pH, and contains high organic load, which can contribute to its environmental toxicity for nations that produce olive oil such as Spain, Greece, Syria, Jordan, and other countries in the Mediterranean (El-Emam, 2023; Khair et al., 2019; Jamrah et al., 2023; Alburquerque, 2004).

The composition of liquid OMW varies with the olive oil extraction system and subsequent filtration. Acidity, dissolved ions, and phenolic compounds are relevant to assessing its potential use as a construction-process liquid, but their effects cannot be inferred from wastewater composition alone. Table 1 presents measurements reported by (Afonso et al., 2025) for four filtered samples from traditional and three-phase continuous extraction systems. These are results for the investigated samples, not universal ranges for OMW or acceptance limits for construction use.

Fig. 3 shows the environmental impacts associated with OMW. It is evident that the discharge of olive oil wastewater possesses the capability to contaminate both aquatic and terrestrial ecosystems (Hamimed

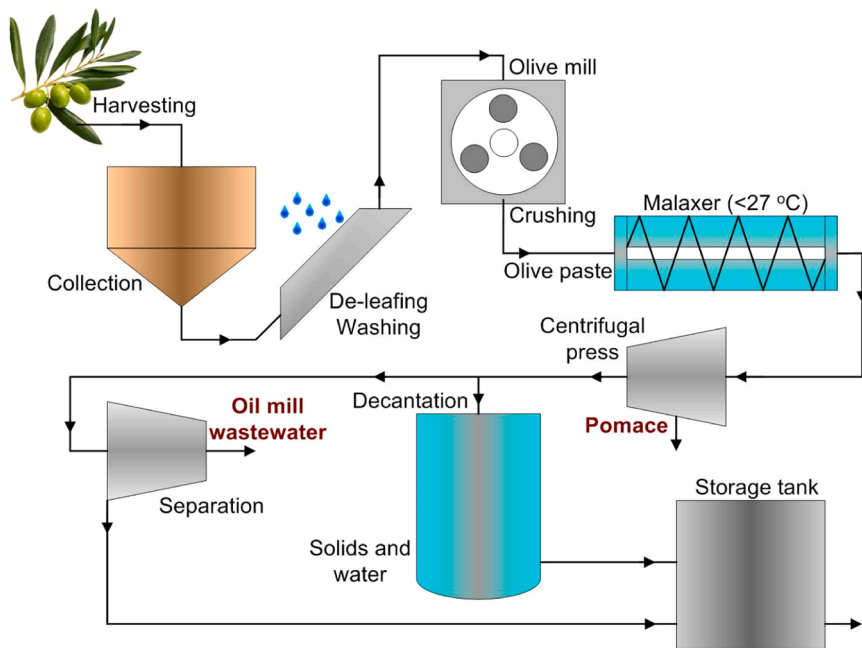


Fig. 2. Schematic representation of a three-phase, centrifugation-based olive oil extraction process with separate oil, pomace, and liquid wastewater streams. Malaxation below 27 °C refers to the temperature shown for that step, not to the method of phase separation (Galloni et al., 2022; Karaouzas et al., 2011).

Table 1
Measured properties of filtered olive mill wastewater from traditional and three-phase continuous extraction systems (data from Afonso et al., 2025).

Parameter	1FC	2FC	1FT	2FT
pH	4.720 ± 0.010	4.710 ± 0.020	4.740 ± 0.000	4.735 ± 0.025
Electrical conductivity (mS/cm)	14.94 ± 0.01	13.87 ± 0.05	20.31 ± 0.05	19.69 ± 0.02
Density (g/cm ³)	1.021 ± 0.001	1.019 ± 0.001	1.032 ± 0.002	1.030 ± 0.001
Total phenolic content (mg EGA/g OMW; source notation)	23.806 ± 0.373	24.071 ± 0.316	29.811 ± 0.192	27.739 ± 0.084

FC = three-phase continuous extraction; FT = traditional extraction; 1 and 2 denote one and two filtration steps, respectively. Values are reported by Afonso et al# (2025) as mean ± standard deviation (n = 3). EGA denotes gallic acid equivalents in the source’s notation. The samples were filtered; the values must not be presented as measurements of untreated OMW.

et al., 2021; Khalil et al., 2024). When OMW is improperly disposed of, either by being directly discharged into the environment or by being

spread on agricultural land without proper treatment, it can lead to soil contamination and groundwater pollution (Barbera et al., 2013).

For construction applications, the environmental concerns illustrated in Fig. 3 lead to two separate questions: whether a particular OMW stream is suitable for manufacturing a material, and whether potentially harmful constituents are released from the finished product. Reusing the effluent does not, by itself, establish either material performance or environmental safety

Global olive oil production is increasing by approximately 5% annually (Mohawesh et al., 2019; Kapellakis et al., 2025), with the Mediterranean basin accounting for approximately 98% of global olive oil production (Jarboui et al., 2023).

Finding an efficient way to convert polluting effluent from olive wastes, especially OMW, into sustainable materials has always been a management challenge (Jarboui et al., 2023). OMW presents a high level of complexity and poses challenges in terms of treatment (Halalsheh et al., 2021).

It is crucial to implement effective treatment and disposal methods to mitigate the environmental impact of OMWs and protect the surrounding environment (S’habou et al., 2009). The high content of organic substances, especially phenolic ones, severely limits the disposal

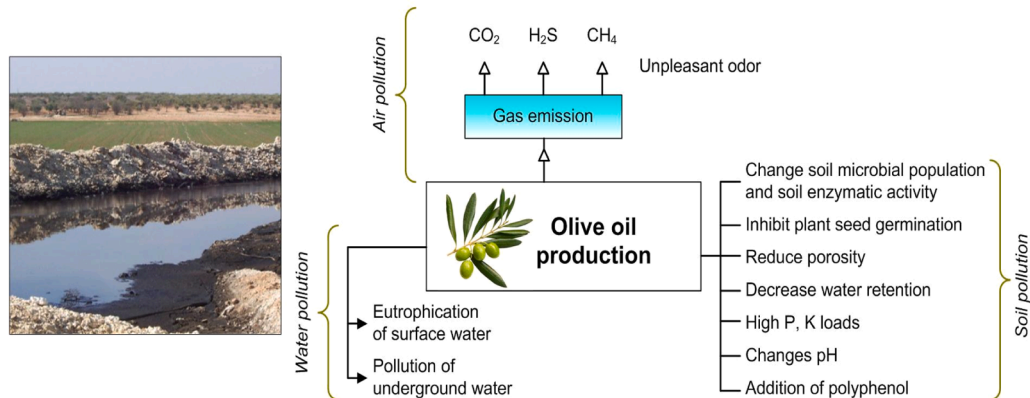


Fig. 3. Impact of olive oil mill wastewater (OMW) on the environment.(Hamimed et al.,2021).

options for these wastewaters. Literature on OMW utilization highlights various approaches, such as biological treatments like aerobic (Alrawashdeh and Al-Essa, 2020) and anaerobic digestion (Vavouraki et al., 2019), which are used to reduce the high organic load while generating biogas. Phytoremediation using specific plant species to absorb contaminants is also explored (Goren et al., 2021), along with composting OMW with agricultural residues to produce organic fertilizers (Martínez-Gallardo et al., 2020). Additionally, advanced oxidation processes (AOPs), including Fenton's reaction and ozonation, are investigated for degrading phenolic compounds in OMW (Domingues et al., 2022), but these purification methods are ineffective when the organic content is high. Membrane filtration technologies can recover valuable polyphenolic compounds from OMW for applications in the pharmaceutical, food, nutraceutical, and cosmetic industries. This approach can reduce the environmental impact of OMW while generating value-added products and supporting a circular-economy approach (Zagklis et al., 2021; Al-Qodah et al., 2022). Land application, after suitable treatment, is another method, where OMW is used to irrigate crops, leveraging its nutrient content (Abboud et al., 2023; Mohawesh et al., 2020). Land application of treated OMW can improve soil fertility, but if not properly managed, it risks soil and water contamination due to the persistence of phenolic compounds and salts. These challenges underscore the need for integrated and optimized strategies for OMW management. Some researchers have recently explored the potential of utilizing OMW as a sustainable alternative to fulfill the water requirements in the manufacturing of concrete or bricks.

Construction use differs from treating OMW for discharge: a defined effluent must be assessed at a defined dosage against the requirements of a finished material. For cementitious materials, the relevant questions include setting, workability, strength, steel-concrete bond, durability, and release of soluble constituents. For fired-clay products, they include forming behavior, drying shrinkage, water absorption, strength, thermal properties, and firing emissions. The following section evaluates published findings against these questions and identifies when a study instead concerns sludge, pomace, or washing effluent.

4. Application of OMW in the construction industry

4.1. Concrete

Imseeh (1997) conducted research on the impact of substituting water with OMW on the properties of fresh and hardened concrete. Concrete mixes having (water+OMW)/cement ratio of 0.4, 0.45, and 0.5 were prepared. Normal mixing water was replaced with olive mill wastewater (OMWW) at replacement levels of 10%, 20%, 30%, and 40%. The results of OMW showed that the workability of fresh concrete improved by increasing the slump between 6% and 400% and that compressive strength at 28 days increased by 1–38% depending on the percentage of water replacement and contents of concrete mixes. In the mixtures assessed by Imseeh (1997), 30% mixing-water replacement was reported as favorable; this result should not be treated as a general optimum for other cements, mixtures, or OMW sources.

Memioğlu and Elibol (2020) tested a multicomponent concrete admixture containing

OMW together with polycarboxylate, molasses, defoamer, biocide, and water. They reported formulations containing up to 9.42 wt% OMW without loss of the measured concrete performance. This percentage refers to the admixture formulation, not to replacement of concrete mixing water, and the outcome cannot be attributed to OMW alone.

Alzgool et al. (2021) investigated the use of olive oil mill wastewater (OMWW) as a partial replacement for mixing water in mortar at replacement levels of 2.5–40%. At 28 days, the maximum compressive strength of 35 MPa was achieved at 7.5% OMWW, representing a 17% increase compared with the control mortar. However, no significant changes in flexural strength were observed at any replacement level.

Alzgool et al. (2022) investigated the steel-concrete bond using

pull-out tests with OMW dosed relative to the mixing water. Although the article's Abstract describes an improvement, its experimental tables, discussion, and conclusions report that bond strength at 7.5% OMW was approximately 6–10% below the reference, depending on reinforcement diameter. This distinction matters because a favorable compressive-strength result does not demonstrate favorable reinforcement bond.

Al-Baijat and Alzgool (2023) have completed an extensive research project examining the effects of incorporating olive oil mill and brine wastewater into concrete mixes to analyze torsion, bending stress, shear, and compressive strength. The torsional strength of the samples containing brine wastewater, when added at the optimal percentage of 10%, was determined to be 5.46 MPa. Similarly, when olive oil mill wastewater was added at the best percentage of 7.5%, the torsional strength was measured to be 5.16 MPa. These values indicate a significant increase in torsional strength compared to the reference samples, which had a torsional strength of 4.38 MPa. Specifically, the addition of brine wastewater resulted in a 24% increase in torsional strength, while the addition of olive oil mill wastewater led to a 17% increase. The measured torsional response is a material-specific result. A net environmental benefit would additionally require assessment of wastewater collection, handling, and the final material.

EL Boukhari et al., (2023a), (2023b) investigated the development of structural concrete with reduced thermal conductivity by incorporating olive waste (OW) as a lightweight aggregate. Two types of olive pomace were used: dry olive pomace (OP) and olive pomace immersed in olive mill wastewater (OP_{WW}), replacing natural sand by equal volume at replacement levels of 0–15%. Each type was evaluated in both dry and saturated conditions. The results showed that concrete incorporating 5% dry olive pomace (OP_{WW}) achieved a compressive strength of 25 MPa and tensile strength of 4.61 MPa, satisfying the minimum requirements for C25/30 structural concrete. In addition, the results showed that there was a 34% reduction in thermal conductivity, highlighting the potential of olive-processing waste for developing structural concrete with enhanced thermal insulation concrete.

EL Boukhari et al., (2023a), (2023b) investigated the incorporation of olive mill wastewater (OMW)-containing olive pomace aggregates (OPMW) as a partial replacement for natural sand in cement mortar. OPA/OPMW were used at 0, 5, 10, and 15% replacement levels in dry and saturated conditions. The 5% dry OPMW mixture provided the best performance, achieving a 28-day compressive strength of 33.50 MPa with only a marginal reduction in strength compared with the reference mortar.

Shuaibi, (2003) studied the use of Olive Mills Wastewater as a water replacement in concrete mixes. The findings indicate that incorporating OMW into a concrete mixture can significantly improve its workability, with an average increase in slump of 140%. Moreover, when replacing 10–20% of the mixture and maintaining a water content of 8–10%, the compressive strength of the concrete is enhanced by an average of 5%. Notably, when using approximately 20% replacement level and a water content exceeding 10%, the addition of OMW yields favorable outcomes. In this scenario, the slump can be increased by 90–200% while keeping the strength results relatively unchanged. Additionally, even after 160 days, concrete samples containing up to 100% OMW replacement exhibit an increase in strength. Use of untreated OMW may avoid a pretreatment step under the conditions investigated, but collection, storage, characterization, transport, and any required quality-control measures remain potential costs.

Qatu and Shuaibi (2024) investigated OMWW as a partial replacement for mixing water in concrete using different w/c ratios (0.35, 0.50, and 0.65), water contents (8%, 10%, and 12%), and OMWW replacement levels (0–100%). The results indicated that the effects of OMWW depended on the w/c ratio and water content. At low w/c ratios, OMWW increased compressive strength by up to 20% without significantly affecting slump, particularly at high replacement levels. At higher w/c ratios, 20–40% OMWW replacement maintained compressive strength

while increasing slump by up to 430%. Long-term testing showed no adverse effect on compressive strength. For the mixtures they tested, [Qatu and Shuaibi \(2024\)](#) identified 12% as an acceptable replacement under their reported water-quality assessment, with increased slump and no reported strength penalty at that level. It is a study-specific result, not a universal allowable OMW dosage.

The observed increases in slump are consistent with a possible dispersing effect of constituents in OMW, but the available evidence does not show that untreated OMW performs equivalently to a commercial superplasticizer. Direct comparisons at matched workability, including setting, strength, admixture compatibility, and durability, are required before such substitution can be recommended.

Taken together, these studies do not show a uniform improvement in concrete performance. Workability, compressive strength, and steel-concrete bond are different outcomes and may change in different directions. Comparisons are further limited when mortar results, reinforced-concrete results, and multicomponent admixture formulations are treated as if they measured the same intervention. Consequently, OMW dosage should be reported together with its basis of calculation, wastewater characteristics, mixture composition, and the property actually tested.

OMW contains dissolved organic compounds, phenolics, ions, and potentially residual oil. Changes in particle dispersion, adsorption of organic constituents, air content, and cement hydration are plausible explanations for changes in workability and hardened structure, but the studies reviewed here do not isolate these pathways for a defined OMW component. They should therefore be treated as proposed mechanisms rather than demonstrated OMW–cement reactions. The decrease in reinforcement bond reported by [Alzgool et al. \(2022\)](#) also shows why compressive strength alone is insufficient to assess reinforced-concrete use.

The findings consistently show that OMW can be effectively utilized in concrete mixes, enhancing specific properties and offering environmental benefits by conserving freshwater and reducing waste disposal needs.

4.2. Brick

[Mekki et al. \(2008\)](#) have investigated the possibility of incorporating olive oil mill wastewater (OMW) in the brick-making process. In this study, the OMW was mixed with clays following the same brick-making procedure. The results showed a significant increase in the volume shrinkage (10%) and the water absorption (12%), while the tensile strength remained constant. The incorporation of OMW in bricks can represent a promising way to valorize this effluent, to rid the environment of a highly polluting wastewater and to save huge and precious amounts of water in a country where water shortage is a serious problem.

[Silvestri et al. \(2021\)](#) mention that the integration of OMW into brickmaking can prevent negative impacts from disposal, reduce heat needed in ceramic production, lower greenhouse gas emissions, and provide economic advantages. An analysis was done on the efficiency of an open-loop circular economy model that reuses OMW in making fired clay bricks. The study assessed technical viability, environmental implications, and economic sustainability. Environmental effects were evaluated through a Life Cycle Assessment, comparing traditional production methods with a system that uses OMW in brickmaking. The findings indicated a decrease of up to 3.1% in the overall Global Warming Potential (GWP) for bricks made from OMW compared to conventional bricks. Additionally, there was a 4.3% reduction in the Abiotic Depletion of fossil fuels.

[Spiliotis et al. \(2019\)](#) have published a study detailing the creation of durable building bricks that exhibit enhanced thermal insulation properties. This was achieved by replacing water in the traditional ceramic clay mixture with olive-mill wastewater (OMW). Using olive-mill wastewater in ceramic production creates lighter bricks with better

thermal insulation and satisfactory strength. It also leads to up to 30% energy savings during firing.

[Hamza et al. \(2013\)](#) conducted research on incorporating effluent OMW sludge (OMWS) with a grain size smaller than 1 mm into fired laboratory-produced clay bricks. The findings indicated that adding 6% OMWS resulted in clay bricks that met standard requirements. Utilizing OMWS in clay bricks shows promise as a sustainable method to utilize this effluent.

[Eliche-Quesada et al. \(2014\)](#) compared freshwater with two separately collected liquids: wastewater from olive washing and wastewater from olive-oil washing. They reported slight improvements in selected brick properties under their extrusion and firing conditions. These streams must be identified separately from the OMW examined in other brick studies; the broader review by [Chraibi et al. \(2022\)](#) also covers different olive-industry co-products.

The study investigated the possibility of replacing freshwater with OMW in the production of clay bricks ([Mekki et al., 2006](#)). Experiments showed that the use of OMW reduces water consumption by 20% due to improved plasticity of the mixture. During the firing process, organic residues from OMW burn off, which reduces the density of bricks, increases their porosity (water absorption up to 14.8%) and provides additional heat generation in the kiln, reducing energy costs. Despite the decrease in the strength of bricks to 9.2–9.0 MPa, their properties remain within the building standards. In addition, the use of OMW reduces the environmental burden due to waste recycling and freshwater conservation. This study demonstrates the potential of OMW as a sustainable alternative in the construction industry, especially in regions with water shortages.

The brick studies reveal a trade-off rather than a consistent improvement in every property. [Mekki et al. \(2008\)](#) reported approximately 10% greater volume shrinkage and 12% greater water absorption while tensile strength remained unchanged. By contrast, [Spiliotis et al. \(2019\)](#) reported lighter bricks, lower thermal conductivity, and lower firing-energy use under their test conditions. Differences in clay, liquid source, shaping, and firing prevent these outcomes from being combined into one generally applicable brick formulation. During molding and drying, constituents of OMW may change clay plasticity and shrinkage. During firing, oxidation of organic constituents may contribute to changes in pore structure. These are plausible pathways, but the balance between open and closed pores, water absorption, thermal conductivity, and mechanical strength depends on the clay and firing schedule. Microstructural and firing-emission measurements are needed to test the proposed pathways; reduced density alone does not prove adequate durability or environmental safety.

4.3. Road construction

[Abaza \(2020\)](#) conducted a study on the impact of incorporating OMW, into the base course of roads to enhance its characteristics. The findings revealed that the addition of olive oil liquid waste as a blending agent to the base course leads to a decrease in the optimal liquid content and an increase in the maximum dry density. Moreover, the utilization of olive oil liquid waste resulted in the elimination of dust up to 7% replacement by liquid waste, making it a suitable blending material for unpaved agricultural roads. As the percentage of olive oil liquid waste in the base course increased, the permeability of the base course decreased, creating a water-resistant layer. Furthermore, there was a noticeable enhancement in CBR values with a higher content of olive oil liquid waste in the base course material.

The investigation by [Miri \(1992\)](#) also explored the utilization of Zebar and lime as additives for soil stabilization. The test outcomes demonstrated a significant increase in strength properties, as evidenced by the CBR values. Moreover, the plasticity was reduced, indicating a promising potential for employing OMW in enhancing and stabilizing the characteristics of road sub-grade.

The reported road-base and soil-stabilization findings are

preliminary and concern different mixtures and test methods. Laboratory changes in dry density, permeability, or California bearing ratio do not establish long-term pavement performance. Field exposure, moisture cycling, runoff quality, and the effect of OMW composition should be assessed before recommending routine use. Table 2 compares the reported construction applications by liquid source, material, dosage basis, observed result, and principal limitation. Fig. 4 illustrates the proposed pathways through which OMW constituents may affect cementitious materials and fired clay bricks, together with the properties needed to test those pathways.

5. Future perspectives

The use of OMW in the construction industry presents a promising avenue for sustainable development, driven by the need to mitigate environmental impacts and utilize industrial byproducts effectively. OMW, a byproduct of olive oil production, is traditionally considered an environmental pollutant due to its high organic content and phenolic compounds. However, its potential applications in construction offer a dual benefit: reducing environmental pollution and creating sustainable construction materials.

Compared to other wastewater reuse strategies, the application of OMW in construction materials represents a novel and underexplored approach. While conventional wastewater recycling focuses primarily on agricultural irrigation or industrial cooling systems, integrating OMW directly into concrete and brick production provides a dual benefit of reducing both water consumption and waste management issues. For instance, treated municipal wastewater is often used in non-potable

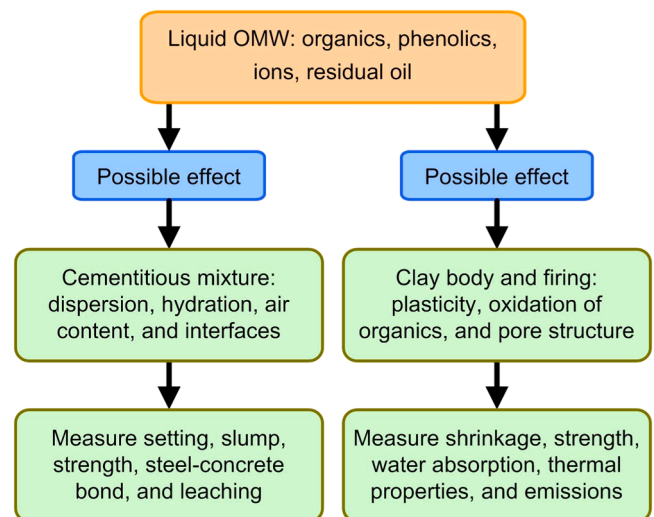


Fig. 4. Conceptual pathways by which constituents of olive mill wastewater may affect cementitious materials and fired clay bricks. Dashed arrows indicate proposed mechanisms, not chemical reactions established by the studies reviewed here. Solid arrows identify the material properties needed to test these proposals. The interpretation is informed by the wastewater characterization of Afonso et al. (2025), the reinforcement-bond results of Alzgoool et al. (2022), and the brick results of Mekki et al. (2008) and Spiliotis et al. (2019).

applications such as landscaping or flushing, but these uses do not

Table 2

Selected evidence on olive-processing effluents and related by-products in construction materials (Percentages in this table use different denominators and must not be compared as a single OMW dosage series. Liquid OMW, washing effluents, sludge, and pomace are identified separately. Results refer to the cited experimental conditions).

Material	What was used; dosage basis	Study-specific result	What limits the conclusion	Reference
Concrete	Liquid OMW replacing mixing water; 30% was favorable in the mixtures discussed	Increased slump and compressive strength were reported for selected mixes	Older, mixture-specific result; 30% is not a universal optimum	Imseeh (1997)
Concrete	Liquid OMW replacing mixing water; 12% under the authors' assessed conditions	Slump increased by 28–178% without a reported strength penalty at that level	The 12% result is study-specific, not a general standard limit	Qatu and Shuaibi (2024)
Cement mortar	Liquid OMW in the mixing liquid; 7.5% identified as favorable in the study	At 28 days, 7.5% OMWW increased compressive strength to 35 MPa (17% above the control), while flexural strength remained largely unchanged.	Mortar results cannot be relabeled as concrete results	Alzgoool et al. (2021)
Cement mortar	Olive pomace immersed in olive mill wastewater (OPWW)	Achieved 33.50 MPa compressive strength at 28 days; higher contents reduced workability and increased porosity.	Mortar results cannot be relabeled as concrete results	EL Boukhari et al., (2023a), (2023b)
Reinforced concrete	Liquid OMW at 7.5% by mass of mixing water	Steel–concrete bond decreased by about 6–10% relative to control	The paper's Abstract contradicts its tables, discussion, and conclusions; use the measured results	Alzgoool et al. (2022)
Concrete made with a formulated admixture	OMW up to 9.42 wt% of the multicomponent admixture	The tested formulations maintained measured performance	Also contained polycarboxylate, molasses and other ingredients; OMW was not tested alone	Memioğlu and Elibol (2020)
Fired clay bricks	Liquid OMW used as a forming liquid	Volume shrinkage rose by about 10%; water absorption by about 12%; tensile strength was unchanged	Favorable waste reuse did not mean every brick property improved	Mekki et al. (2008)
Fired clay bricks	Liquid OMW substituted for forming water	Lower density and thermal conductivity; up to 30% lower firing energy	Energy result depends on the tested firing conditions; it is not freshwater savings	Spiliotis et al. (2019)
Extruded clay bricks	Olive-washing water or olive-oil-washing water, each used as the molding liquid at 22 wt% relative to clay	Slight improvements in selected properties compared with freshwater control	These are distinct washing effluents; 22 wt% is liquid added to clay, not “22% OMW replacement”	Eliche-Quesada et al. (2014)
Concrete with sand replacement	Olive pomace, including pomace conditioned with OMW; aggregate replacement	A selected olive-waste mixture showed favorable mechanical results	Cannot isolate the effect of liquid OMW or describe the dose as water replacement	EL Boukhari et al., (2023a), (2023b)
Fired clay bricks	OMW sludge, added as a solid residue	Selected laboratory bricks met the requirements assessed in that study	Sludge is not liquid OMW	Hamza et al. (2013)
Road base	Olive oil liquid waste used as a blending fluid	Changes in dry density and bearing-related properties were reported	Dose definition and long-term field performance require separate assessment	Abaza (2020)

address the challenge of large-scale industrial water demands. In contrast, OMW utilization in concrete mixes can enhance mechanical properties, such as compressive strength and durability, while simultaneously reducing reliance on freshwater. Previous studies have demonstrated that partial replacement of conventional mixing water with OMW can maintain concrete strength while improving its workability. In particular, [Qatu and Shuaibi \(2024\)](#) reported that OMW could replace up to 12% of the mixing water without exceeding the relevant ASTM limit. At this replacement level, the concrete slump increased by 28–178% without adversely affecting its strength.

Moreover, incorporating OMW into brick production has shown promising results in reducing thermal conductivity and enhancing energy efficiency during the firing process. This innovative reuse strategy addresses both environmental and economic concerns, offering a sustainable solution for countries with high olive oil production and limited water resources.

In terms of potential applications, OMW can be integrated into various aspects of construction. One of the most explored areas is its use in concrete production, where OMW can partially substitute water. This not only reduces the demand for freshwater resources but also potentially enhances the mechanical properties of concrete, such as its compressive strength and durability. Additionally, OMW can be processed into bio-based admixtures and additives for cement, improving workability, setting times, and reducing the carbon footprint of cement manufacturing. Another application is in soil stabilization, particularly in regions with arid or degraded soils. The organic components of OMW can enhance soil properties, making it more suitable for construction projects. Furthermore, in road construction, OMW could provide an eco-friendly alternative to traditional materials, potentially offering improved performance and cost savings.

However, the integration of OMW into construction materials is not without challenges. One of the primary technical challenges is the variability in the composition of OMW, which depends on factors such as the type of olives used, processing methods, and storage conditions. This variability can affect the consistency and performance of OMW-based construction materials, necessitating standardized treatment processes to ensure quality control. Additionally, there are concerns about the long-term stability of OMW in construction materials, particularly the potential for leaching of harmful substances over time. This poses environmental and health risks that must be addressed through rigorous testing and development of safe encapsulation methods. From a practical standpoint, industries and policymakers can leverage OMW-based construction materials to address pressing challenges in water-scarce regions. These materials not only reduce dependency on freshwater in the production process but also enhance the thermal and mechanical properties of bricks and concrete, making them suitable for harsh climates.

For instance, in water-scarce areas, replacing fresh water with treated OMW could reduce freshwater consumption and potentially lower production costs, while simultaneously reducing the environmental burden associated with OMW disposal. The magnitude of these economic benefits would depend on local water prices, treatment requirements, transportation, and disposal costs.

Policymakers can incentivize the adoption of such technologies through subsidies for treatment facilities, tax benefits for sustainable practices, or integrating these materials into green building certifications. These steps would bridge the gap between environmental sustainability and economic practicality, fostering innovation in both the olive oil and construction industries.

Research needs in this area are significant and multifaceted. Firstly, there is a need for comprehensive studies to understand the effects of different OMW treatment methods on its suitability for construction applications. This includes investigating how various treatments impact the physical and chemical properties of OMW and its performance in construction materials. Secondly, research should focus on developing standardized protocols for the treatment and use of OMW in

construction, ensuring consistency and safety. Moreover, long-term studies are necessary to assess the durability and environmental impact of OMW-based materials, particularly their behavior under different environmental conditions and over extended periods.

The economic feasibility of utilizing OMW in construction materials is a critical factor in their broader adoption. While OMW offers a sustainable alternative to conventional additives, the associated treatment and transportation costs must be considered. Treatment processes, such as filtration, sedimentation, or chemical stabilization, add operational expenses that vary depending on the scale and the complexity of the technology used. For instance, the treatment cost of OMW can vary substantially depending on the treatment technology, treatment efficiency, energy requirements, and local operating conditions. Transportation costs can further influence feasibility, particularly in regions where olive mills are distant from construction sites. Developing localized collection and processing hubs near olive-producing regions could mitigate these expenses and make OMW-derived materials more competitive.

Despite these promising findings, several research gaps remain regarding the use of OMW in construction materials. Firstly, there is limited data on the long-term performance and durability of concrete and bricks produced with OMW under varying environmental conditions. Most existing studies focus on short-term mechanical properties without addressing potential degradation over time or the impact of factors such as freeze-thaw cycles, chemical exposure, and weathering. Secondly, the variability in the chemical composition of OMW, influenced by factors such as olive variety, processing methods, and storage conditions, presents a challenge for standardizing its use in construction. Further research is needed to establish guidelines for the safe and consistent incorporation of OMW into building materials. Additionally, the environmental impact of potential leaching of organic compounds from OMW-based materials has not been fully explored. Addressing these gaps is essential to ensure the sustainable and practical application of OMW in the construction industry. Future experiments should report the olive oil extraction system, OMW storage and pretreatment, pH, electrical conductivity, organic and phenolic load, relevant dissolved salts, and the precise basis of dosage. Matched reference mixtures should then be tested for setting and hydration, microstructure, strength at multiple curing ages, and, for reinforced concrete, steel-concrete bond. Durability testing should reflect the intended exposure and include appropriate moisture, freeze-thaw, or chemical cycles rather than assuming resistance from short-term strength. Finished materials should be assessed for the release of relevant constituents; brick studies should additionally measure firing emissions. These data are needed before a long-term performance claim or a generally acceptable OMW percentage can be established.

To safely and effectively integrate OMW into construction materials, the development of standardized guidelines and protocols is essential. First, it is necessary to establish clear requirements for the characterization of OMW, including parameters such as pH, organic content, and heavy metal concentrations, to ensure consistency in material performance and environmental safety. Alongside this, acceptable treatment methods must be defined, such as filtration, neutralization, or biological treatment, to reduce toxicity and variability in OMW composition. Equally important is the need for recommendations on optimal OMW dosages tailored to specific construction materials, such as concrete or bricks, to achieve desired performance properties like compressive strength and thermal insulation. Additionally, protocols should address potential environmental and health risks, including the leaching of contaminants or emissions during material curing, ensuring compliance with relevant regulations. Finally, robust quality control measures must be implemented, requiring regular testing of both untreated OMW and the final construction products to verify adherence to these standards. By establishing these comprehensive guidelines, industries can safely utilize OMW in a controlled and scalable manner, promoting environmental sustainability and advancing the circular economy in the

construction sector

6. Limitations of this review

This review is limited by the relatively small number of available studies investigating the use of olive mill wastewater (OMW) in construction materials. Differences in OMW composition, replacement levels, material types, and experimental conditions also make direct comparisons between studies difficult. In addition, limited long-term durability and field-scale data are available, and standardized guidelines for the use of OMW in construction materials are lacking. Further experimental and field-scale studies are therefore needed to evaluate the long-term performance, environmental safety, practical feasibility, and optimum OMW replacement level in construction applications, thereby supporting its potential as a sustainable alternative to conventional mixing water.

7. Conclusion

There has been a lack of extensive research on the use of OMW in construction projects. Nevertheless, this study highlights the significance of incorporating OMW into specific construction materials, especially in areas that are dealing with environmental difficulties and water scarcity problems.

Experimental studies indicate that liquid olive mill wastewater (OMW) can partially replace mixing water in selected concrete mixtures, although the results depend on mix design. Qatu and Shuaibi (2024) reported slump increases of up to 430% and an average increase in compressive strength of approximately 5%. At a 12% OMW replacement level in their study, slump increased by 28–178% without a reported loss of strength. These figures describe different tested mixtures rather than a single optimal dosage. For reinforced concrete, Alzgool et al. (2022) found that adding OMW at 7.5% of the mixing-water mass reduced steel–concrete bond strength by approximately 6–10% relative to the controls. Workability gains must therefore be assessed alongside strength, setting, durability, and bond performance; the available studies do not establish a universal optimum or equivalence to a commercial superplasticizer.

For fired-clay bricks, Spiliotis et al. (2019) reported lower density and thermal conductivity and measured up to 30% lower firing-energy consumption under their experimental conditions. By contrast, Mekki et al. (2008) observed approximately 10% greater volume shrinkage and 12% higher water absorption, while tensile strength remained unchanged. The 30% figure refers to firing energy, not to a measured reduction in freshwater consumption. These contrasting results show that the suitability of OMW depends on the effluent, clay composition, and manufacturing conditions. Long-term durability, firing emissions, and leaching require further testing before routine construction use can be recommended.

CRediT authorship contribution statement

Imad A. Al-Qasem: Supervision. **Mohanad Yaseen Abdulwahid:** Writing – original draft. **Daniel Jato-Espino:** Writing – review & editing. **Valentin Romanovski:** Writing – review & editing, Writing – original draft.

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The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in the paper.

Data availability

The data that has been used is confidential.

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