



## AN EFFECTIVE, FEASIBLE, AND PRACTICAL MANAGEMENT OF OLIVE MILL WASTEWATER (OMW)

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### ABSTRACT

Climate change and water scarcity are pressing global challenges, impacting ecosystems and human livelihoods, underscoring the urgent need for sustainable water management practices. As a byproduct of olive oil production, olive mill wastewater (OMW) poses environmental challenges due to its high organic content and toxicity. To address this, various treatments, ranging from physical and biological to advanced methods, have been evaluated to manage OMW. The objective is to reduce its organic load, mitigate associated toxins, and investigate its potential for utilization in irrigation and fertilization. The investigation involved assessing multiple parameters [pH, EC, turbidity, DO, COD, BOD, TSS, TDS, cations, anions, macro and micro nutrients, heavy metals, and polyphenols] before and after each treatment. This approach shows promising potential in achieving significant treatment efficacy. Furthermore, innovative treatments for olive mill wastewater carry immense significance in conserving water resources for future generations, endorsing sustainable agricultural practices, and shielding ecosystems from the harmful impacts of untreated waste.

## INTRODUCTION

Climate change is acknowledged as the pivotal challenge of our era, giving rise to a spectrum of natural disasters such as floods, landslides, droughts, storms, sea-level rise, and various other calamities (Moustafa *et al.*, 2023). The surge in global warming is primarily fueled by human emissions of greenhouse gases, leading to substantial changes in Earth's climate and consequential impacts on the environment.

According to the Intergovernmental Panel on Climate Change, temperatures rose by 1°C over pre-industrial levels in 2017 and could rise by 3.5°C by 2100. These modifications will have an effect on communities all across the world by reducing the availability of water by 20% (Ungureanu *et al.*, 2020). The Mediterranean region expects altered precipitation patterns,

decreased rainfall, and increased temperatures as a result of climate change (Rocha *et al.*, 2020).

Global water scarcity, a barrier to Sustainable Development Goals, has both local and global causes (Dolan *et al.*, 2021). Water scarcity, where demand exceeds supply, results in inadequate access to safe water, impacting human well-being and the environment (Rosa *et al.*, 2020). Approximately 20 million hectares of fertile land degrade annually, endangering livelihoods, with one-third of agricultural land degrading in the past 40 years (AbdelRahman, 2023).

Drylands, covering nearly 40% of the Earth's land area, sustain around two billion people, but their food security faces threats from factors like land use, climate change, and soil erosion (Abuzaid *et al.*, 2021).

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Deserts, with limited vegetation, expand at ecological and social costs (Wu *et al.*, 2023). Olive trees are found in the Mediterranean region, with 97% of global cultivation occurring there (Foti *et al.*, 2021).

Cultivation of the olive tree (*Olea europaea* L.) for the production of olive oil represents one of the oldest agricultural practices in human history. Olive oil holds great significance in the Mediterranean diet due to its high nutritional value and associated health benefits. Olive trees are predominantly cultivated in the Mediterranean region, Europe, the Middle East, the United States, Argentina, and Australia (Sygouni *et al.*, 2019).

The process of extracting olive oil involves various stages, including washing the olives, crushing, malaxation to break the emulsion, and finally, separating and extracting the oil. Over time, advancements in technology and increased oil output have led to improvements in olive oil extraction procedures, enhancing the overall quality of the end product (Abou-Zaid, 2021).

The extraction of olive oil results in the generation of olive mill wastewater (OMW). OMW is a dark, brown-colored liquid with a pH range of 3–6, consisting of a stable emulsion of vegetative water, water added during processing, olive fruit, residual oil, and olive pulp fragments (Shabir *et al.*, 2022). Due to its significant pollutant content, OMW poses a substantial environmental threat in olive oil-producing countries. The composition of OMW is influenced by extraction technology, processed fruits, and processing conditions. OMW, with its complex chemical structure and diverse characteristics, poses challenges for direct industrial use as a raw material (Chatzistathis *et al.*, 2021).

Among the problematic components of olive mill waste effluents are the phenolic

contents, comprising both low and high molecular weight compounds, including tannins and anthocyanins. The chemical oxygen demand (COD) and biological oxygen demand (BOD) levels in OMW range from 40 to 220 g L<sup>-1</sup> and 35–110 g L<sup>-1</sup>, respectively, indicating significant organic pollution (Al-Qodah *et al.*, 2022; Cecchi *et al.*, 2018; Nunes *et al.*, 2018; Tufariello *et al.*, 2019;).

In the agricultural lands of Mediterranean regions, OMW has been studied as a potential organic fertilizer due to its relatively high organic content and nutrient composition, particularly potassium and phosphorus (Magdich *et al.*, 2020). The olive oil industry generates significant wastewater and solid waste, posing environmental challenges (Martins *et al.*, 2021).

OMW consists of water (83–94% W/W) and organic components (4–18% W/W), including sugars, tannins, polysaccharides, phenolic compounds, organic acids, and lipids (Domingues *et al.*, 2021; Shabir *et al.*, 2023; Tundis *et al.*, 2020). The disposal of OMW has positive effects on the environment, promoting plant development and serving as a soil conditioner, fuel, source of valuable products (such as methane, biogas, bihydrogen), compost, or as a starting material for the production of essential goods like antioxidants and enzymes. Additionally, olive mill solid residue has the potential to remove heavy metals through biosorption (Khalil *et al.*, 2021).

OMW can be used in a circular economy and as a source of polyphenols for plant protection, replacing chemical pesticides (Leontopoulos *et al.*, 2020; Silvestri *et al.*, 2021). This study focuses on reusing and treating olive mill wastewater, evaluating various treatment technologies and their environmental impacts, and discussing potential solutions for managing this waste.

## MATERIALS AND METHODS

### Experimental System

Olive Mill Wastewater (OMW) was obtained directly from the outlet of an olive mill plant and subsequently stored in an uncovered concrete tank at the Faculty of Agricultural Sciences. Prior to conducting the experiment, the wastewater was subjected to dilution with water.

### Olive Mill Wastewater Treatment

#### Primary treatment (physical treatment)

This step aimed to remove heavy suspended and floating solids through sedimentation, flotation, and filtration processes, resulting in treated water labeled as A<sub>1</sub>.

#### Secondary treatment (physicochemical treatment)

This stage aimed to eliminate remaining dissolved organic matter that may have escaped the physical treatment. The wastewater undergoes continuous aeration and stirring for 8 hours daily (*i.e.*, aerobic conditions) for 3 weeks, followed by filtration. Subsequently, the filtered water is stored for another 3 weeks in a well-closed tank (*i.e.*, anaerobic conditions), filtered again, and then treated with Ca (OH)<sub>2</sub> as a coagulant (60g/100 L), labeled as A<sub>2</sub>.

#### Advanced physicochemical treatment

The final filtrate from the preceding stage was subjected to treatment with granular activated carbon (G.A.C) as an adsorbent (80 g/100 L). Following a 3-week period, it underwent another filtration and labeled as A<sub>3</sub>.

### Physical and Chemical (Physicochemical) Determination in Water Samples

#### Physical and physicochemical characteristics in water samples

All samples gathered for chemical and biochemical analyses were preserved in an icebox and promptly transported to a central laboratory at Zagazig University. The measured parameters included pH,

electrical conductivity (E.C), turbidity (NTU), total dissolved solids (TDS), total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), and dissolved oxygen (D.O). Analytical-grade reagents from BDH and Sigma Chemical Companies were utilized.

#### Chemical characteristics in samples

The chemical parameters encompassed macro nutrients (cations: Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>+2</sup>, Mg<sup>+2</sup>), anions (CO<sub>3</sub><sup>-2</sup>, HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>-2</sup>, PO<sub>4</sub><sup>-3</sup>, NO<sub>3</sub><sup>-</sup>), micronutrients (Fe, Zn, Cu, Mn, B), heavy metals (Pb, Cd, Ni, Co, Cr), and total polyphenols. The concentrations of heavy metals were determined using an atomic absorption spectrophotometer (A.A.S) (Perkin Elmer, Model Analyst A 7000). Additionally, polyphenols were extracted from OMW samples following the ASTM (2002).

#### Statistical Analysis

Mean comparisons were performed using Duncan's multiple ranges test (DMRT) at a 5% probability level, following Duncan's Methodology (Duncan, 1958), a randomized complete block design (RCBD) with 12 samples and 3 replicates were used, same letters are not significantly (P<0.05) different according to the DMR test.

## RESULTS

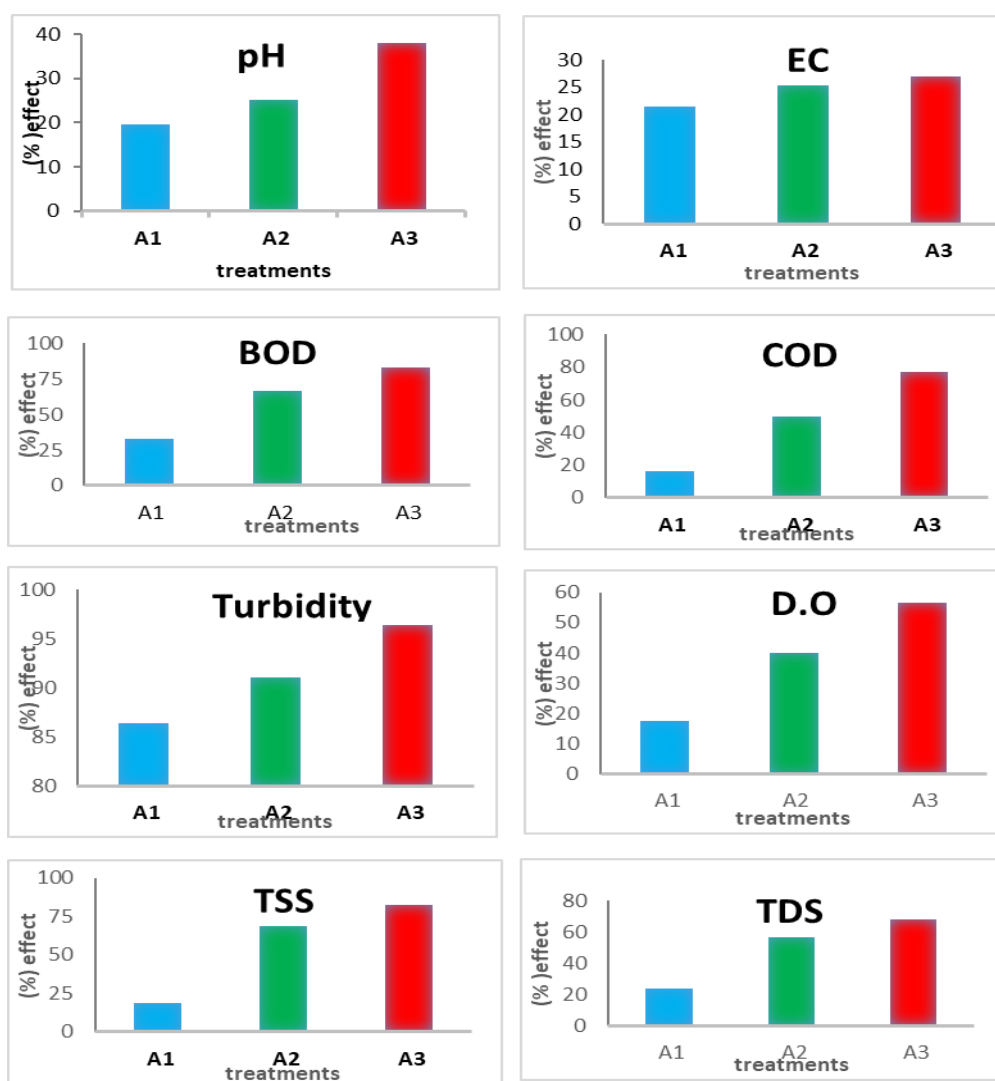
According to Table 1, it is apparent that the pH value increased in treatment A<sub>1</sub> compared to the control B by an effect percentage of 19.6%, indicating a reduction in acidity. Similarly, the electrical conductivity value in treatment A<sub>1</sub> (8.12) showed an increase of 21.4% compared to the control (B) (6.69). Conversely, there was a significant decrease in the values of turbidity, dissolved oxygen (D.O), chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), and total dissolved solids (TDS) in treatment A<sub>1</sub> compared to the control B. The least percentage of effect was observed in COD with a value of (16.5%), while the highest percentage of effect was recorded in turbidity with a value of (86.4%).

**Table 1. Effect of physical treatments on physiochemical characteristics in water samples of olive mill wastewater (OMW)**

Treatment	pH	EC (dS m <sup>-1</sup> )	Turbidity (NTU)	D.O (mg/L)	COD (g/L)	BOD (g/L)	TSS (g/L)	TDS (g/L)
<b>B</b>	5.55±0.09d	6.69±0.07c	410.33±1.53a	13.28±0.316a	51.74±0.37a	26.16±0.57a	47.01±0.41a	14.21±0.69a
<b>A<sub>1</sub></b>	6.64 ±0.03c	8.12±0.03b	55.90 ±1.10b	10.97 ±0.47b	43.21±0.83b	17.51±0.19b	38.14±0.72b	10.79±0.30b
<b>A<sub>2</sub></b>	6.95±0.19b	8.39±0.09a	36.86 ±0.82c	7.97 ±0.57c	26.16±0.63c	8.83 ±0.39c	14.5 ±0.69c	6.14±0.26c
<b>A<sub>3</sub></b>	7.66 ±0.16a	8.50±0.23a	14.81 ±0.66d	5.76 ±0.28d	11.88±0.41d	4.48 ±0.52c	8.18 ±0.30d	4.55 ±0.21d

Results are means ± standard deviation for each analyzed parameter, a randomized complete block design (RCBD) with 12 samples and 3 replicates were used, same letters are not significantly ( $P < 0.05$ ) different according to the DMR test.

**B** (Raw olive mill wastewater), **A<sub>1</sub>** (Primary treatment), **A<sub>2</sub>** (Secondary treatment), **A<sub>3</sub>** (Advanced treatment) **pH** (potential of Hydrogen), **EC** (Electrical Conductivity), **D.O** (Dissolved Oxygen), **COD** (Chemical Oxygen Demand), **BOD** (Biochemical Oxygen Demand), **TSS** (Total Suspended Solids), **TDS** (Total Dissolved Solids), **% effect** (percentage effect).

**Fig. 1. Percentage effect of physical treatments on physiochemical characteristics in water samples of olive mill wastewater (OMW)**

Similarly, in the second treatment ( $A_2$ ), the pH value increased to reach 6.95, indicating lower acidity compared to the control. Additionally, there was an observed increase in the electrical conductivity percentage of effect, reaching 25.4%. Regarding the values of turbidity, dissolved oxygen (D.O), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and total dissolved solids (TDS), there was a clear decrease in all values. The maximum decrease was observed in turbidity at a percentage of effect of 91%, while the minimum decrease was recorded in the parameter D.O level at a percentage of effect of 40%.

In the third treatment ( $A_3$ ), the situation is similar to what was mentioned earlier, with the highest pH value recorded at 7.66, making it the least acidic among the other treatments. The electrical conductivity percentage of effect also increased to its highest level, reaching 27.1%. The pattern is consistent in the values of turbidity, D.O, BOD, COD, TSS, and TDS, where a significant decrease in values was observed with the highest reduction rates recorded for the treatments. The highest percentage of effect was in turbidity, reaching 96.4%, while the lowest reduction was observed in the D.O value with a percentage of effect of 56.6%.

Based on the above, it is clear that treatments  $A_1$ ,  $A_2$ , and  $A_3$ , in terms of their effect on the physicochemical characteristics, can be arranged in ascending order based on the average percentage of effect for all tested parameters (turbidity, D.O, COD, BOD, TSS, and TDS) for each treatment:  $A_1 > A_2 > A_3$  with values of 30.83, 24.61, and 12.63, respectively.

The effects of several physical treatments on the amounts of macronutrients (cations) in olive mill wastewater (OMW) are shown in Table 2. Comparing the principal treatment ( $A_1$ ) to the control (B), the

concentrations of  $Na^+$ ,  $K^+$ ,  $Ca^+$ , and  $Mg^+$  were reduced by percentages of (23.2%, 18.7%, 28.7%, and 20.5%), respectively.

As the treatments progressed to  $A_2$  and  $A_3$ , there was a consistent decline in the levels of these cations.  $A_2$  displayed a further reduction in  $Na^+$ ,  $K^+$ ,  $Ca^+$ , and  $Mg^+$  by (30.5%, 37.2%, 42.2%, and 36.2%) respectively, while  $A_3$  exhibited the most significant reductions, recording percentages of (40.9%, 54.2%, 50.2%, and 42.9%) for  $Na^+$ ,  $K^+$ ,  $Ca^+$ , and  $Mg^+$  respectively, compared to the control (B).

These observations indicated that as the physical treatments progressed from  $A_1$  to  $A_3$ , there was a notable decrease in the concentrations of these macro nutrients ( $Na^+$ ,  $K^+$ ,  $Ca^+$ , and  $Mg^+$ ) in the olive mill wastewater, signifying the efficacy of the treatments in altering the cationic composition of the water samples.

From the above, the average percentage of effect for all tested parameters (macro nutrients) (cations) ( $Na^+$ ,  $K^+$ ,  $Ca^+$ , and  $Mg^+$ ) was as follows:  $A_1 < A_2 < A_3$  with values of (22.78%, 36.52%, and 47.05%), respectively.

The effects of several physical treatments on the concentrations of macronutrients (anions) in water samples containing olive mill effluent (OMW) were displayed in Table 3.  $HCO_3^-$ ,  $Cl^-$ ,  $SO_4$ ,  $PO_4$ , and  $NO_3$  concentrations were found to be lower in the primary treatment ( $A_1$ ) as compared to the control B by percentages of 5.04%, 1.92%, 5.04%, 26.50%, and 15.39%, respectively.

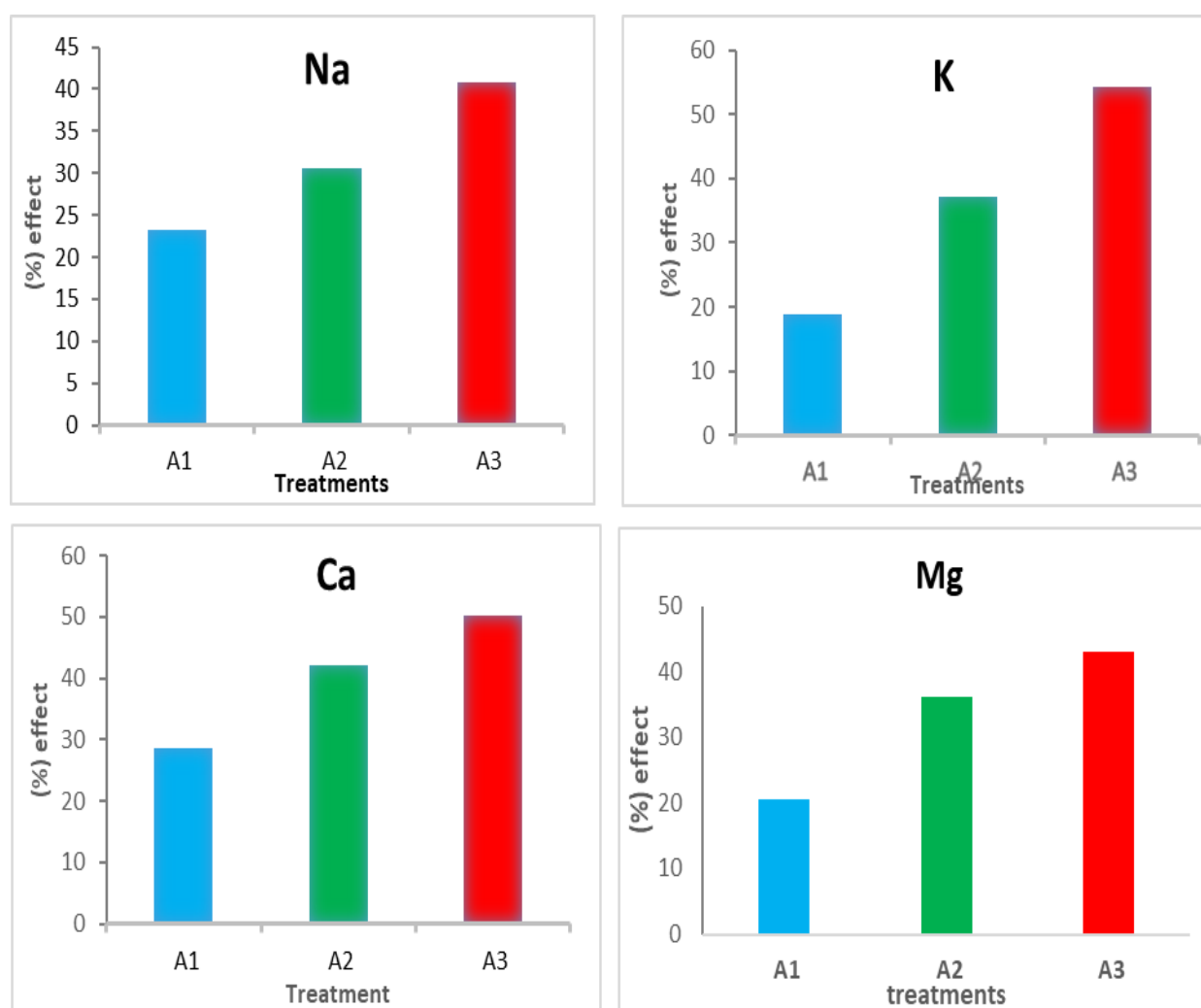
The levels of these anions continuously decreased as the treatments advanced to  $A_2$  and  $A_3$ .  $HCO_3^-$ ,  $Cl^-$ ,  $SO_4$ ,  $PO_4$ , and  $NO_3$  were further reduced by percentages in  $A_2$  (8.72%, 5.84%, 11.66%, 28.85%, and 28.48%), while  $A_3$  showed the greatest reductions in comparison to B, with percentages of (14.79%, 20.99%, 28.59%, 51.87%, and 44.89%) for  $HCO_3^-$ ,  $Cl^-$ ,  $SO_4^{2-}$ ,  $PO_4^{3-}$ , and  $NO_3^-$  respectively. No measurable amounts of  $CO_3^{2-}$  were detected in any of the water samples.

**Table 2. Effect of physical treatments on levels of macro nutrients (cations) in water samples of olive mill wastewater (OMW)**

Treatment	Na <sup>+</sup> (mg/L)	K <sup>+</sup> (mg/L)	Ca <sup>+</sup> (mg/L)	Mg <sup>+</sup> (mg/L)
<b>B</b>	49.48 ±0.89a	11.10 ±0.77a	13.35 a ±0.53a	13.32 a ±0.56a
<b>A<sub>1</sub></b>	38.01 ±0.18b	9.02 ±0.49b	9.52 c±0.87b	10.59 ±0.15b
<b>A<sub>2</sub></b>	34.38 ±0.60c	6.97 ±0.38c	7.72 d±0.76c	8.50 ±0.19c
<b>A<sub>3</sub></b>	29.26 ±1.23d	5.0 ±0.65d	6.65 d±0.93c	7.60 ±0.19d

Results are means ± standard deviation for each analyzed parameter, a randomized complete block design (RCBD) with 12 samples and 3 replicates were used, same letters are not significantly ( $P < 0.05$ ) different according to the DMR test.

**B** (Raw olive mill wastewater), **A<sub>1</sub>** (Primary treatment), **A<sub>2</sub>** (Secondary treatment), **A<sub>3</sub>** (Advanced treatment), **Na<sup>+</sup>** (Sodium), **K<sup>+</sup>** (Potassium), **Ca<sup>+</sup>** (Calcium), **Mg<sup>+</sup>** (Magnesium), **% effect** (percentage effect).

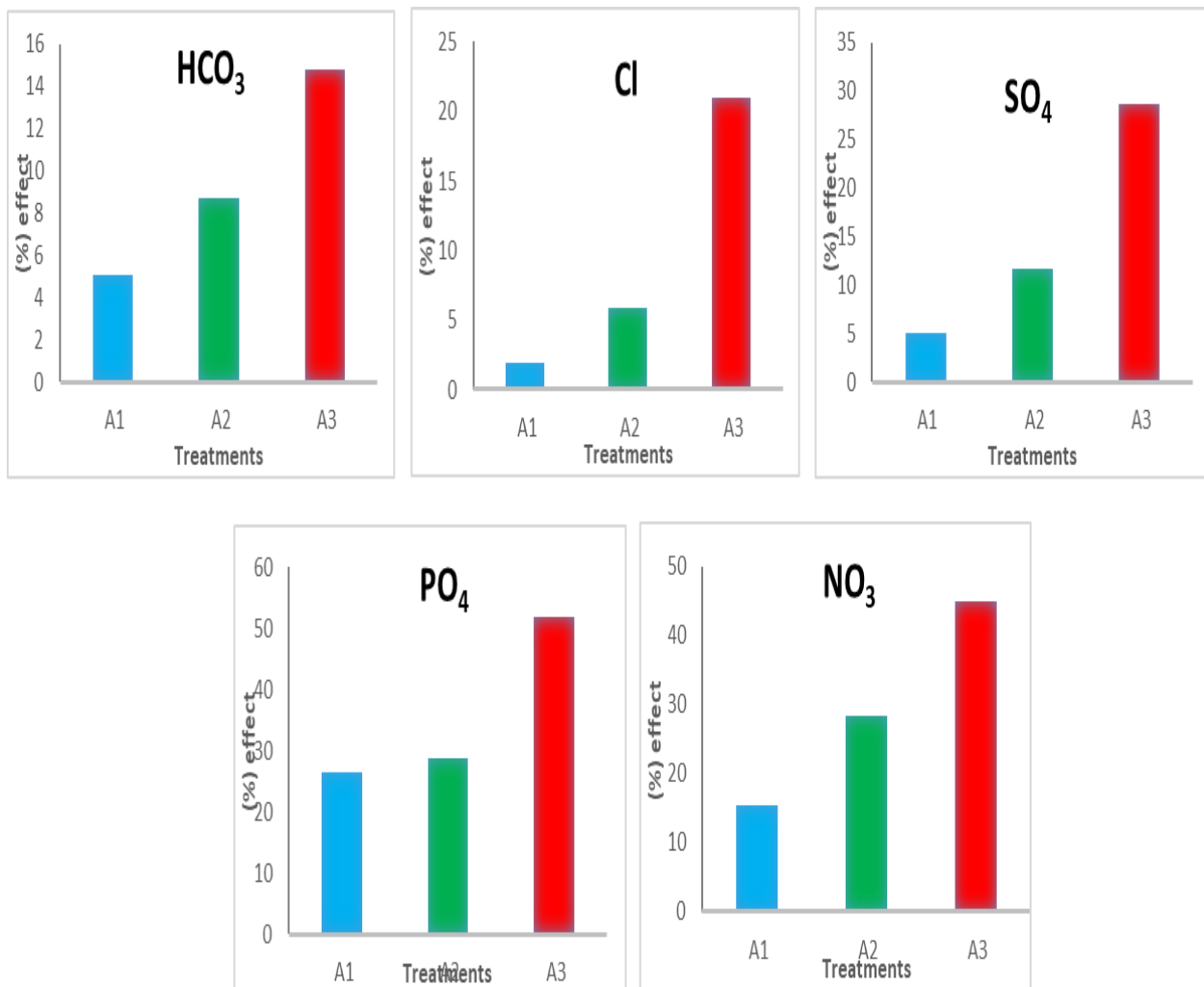
**Fig. 2. Percentage effect of physical treatments on levels of macro nutrients (cations) in water samples of olive mill wastewater (OMW)**

**Table 3. Effect of physical treatments on levels of macro nutrients (anions) in water samples of olive mill wastewater (OMW)**

Treatment	$\text{HCO}_3^{-2}$ (mg/L)	$\text{Cl}^-$ (mg/L)	$\text{SO}_4^{-2}$ (mg/L)	$\text{PO}_4^{-3}$ (mg/L)	$\text{NO}_3^-$ (mg/L)	$\text{CO}_3^{-2}$ (mg/L)
B	29.14 ±0.43a	27.06 ±0.46a	26.76 ±0.37a	641.33 ±4.04a	649.66 ±4.51a	nd
A <sub>1</sub>	27.67 ±0.40b	26.54 ±0.16ab	25.41 ±0.22b	471.33 ±5.03b	549.66 ±3.51b	nd
A <sub>2</sub>	26.60 ±0.19c	25.48 ±1.11b	23.64 ±0.17c	456.33 ±5.51c	464.66 ±12.66c	nd
A <sub>3</sub>	24.83 ±0.94d	21.38±0.40c	19.11 ±0.44d	308.66 ±3.51d	358 ±8.19d	nd

Results are means ± standard deviation for each analyzed parameter, a randomized complete block design (RCBD) with 12 samples and 3 replicates were used, same letters are not significantly ( $P < 0.05$ ) different according to the DMR test.

**B** (Raw olive mill wastewater), **A<sub>1</sub>** (Primary treatment), **A<sub>2</sub>** (Secondary treatment), **A<sub>3</sub>** (Advanced treatment),  $\text{HCO}_3^{-2}$  (Bicarbonate),  $\text{Cl}^-$  (Chloride),  $\text{SO}_4^{-2}$  (Sulfate),  $\text{PO}_4^{-3}$  (Phosphate),  $\text{NO}_3^-$  (Nitrate),  $\text{CO}_3^{-2}$  (Carbonate), % effect (percentage effect), **nd** (non detected).

**Fig. 3. Percentage effect of physical treatments on levels of macro nutrients (anions) in water samples of olive mill wastewater (OMW)**

These findings imply that the concentrations of these macronutrients (anions) in the olive mill wastewater decreased noticeably as physical treatments advanced from A<sub>1</sub> to A<sub>3</sub>, indicating the effectiveness of the treatments in changing the anionic composition of the water samples. A<sub>1</sub><A<sub>2</sub><A<sub>3</sub> with values of (8.98%, 13.92%, and 26.86%), respectively, was the average percentage of effect for all measured parameters (macro nutrients) (anions) (HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>-2</sup>, PO<sub>4</sub><sup>-3</sup>, and NO<sub>3</sub><sup>-</sup>).

Results in Table 4 show that B displayed the highest concentrations for reach of Fe, Zn, B, Mn and Cu. As the treatments progressed from A<sub>1</sub> to A<sub>3</sub>, there were consistent reductions in the concentrations of these micronutrients. A<sub>1</sub> showed a decrease by percentages effect of (38.7%, 12.8%, 56.7%, 7.5% and 19.3%) for Fe, Zn, B, Mn and Cu respectively compared to the control B.

Subsequent treatments A<sub>2</sub> and A<sub>3</sub>, demonstrated further declines in these micronutrient levels. A<sub>2</sub> showed reductions by percentages effect of (49.3%) for Fe, (35.6%) for Zn, (64.4%) for B, (34.8%) for Mn and (30.7%) for Cu compared to B. Meanwhile, A<sub>3</sub> displayed the most significant reductions, with percentages effect of (69.1%, 42.7%, 75.1%, 56.3% and 59.4%) for Fe, Zn, B, Mn and Cu, respectively compared to (B).

Based on the provided information, the average percentage of impact for the micronutrients (Fe, Zn, B, Mn, and Cu) was as follows: A<sub>1</sub> recorded a percentage of impact of (26.99%), A<sub>2</sub> demonstrated a percentage of impact of (42.94%), and A<sub>3</sub> exhibited the most substantial percentage of impact at (60.50%).

Results in Table 5 illustrate that B displayed the highest concentrations of Pb, Cd, Ni, Co, Cr, and polyphenols. As the treatments progressed from A<sub>1</sub> to A<sub>3</sub>, there were consistent reductions in the

concentrations of these parameters. A<sub>1</sub> showed decreases by percentage effects of (69.1%, 63.6%, 16.3%, 23.5%, 42.7%, and 17.7%) for Pb, Cd, Ni, Co, Cr, and polyphenols, respectively, compared to the control B. Subsequent treatments, A<sub>2</sub> and A<sub>3</sub>, demonstrated further declines in these parameters.

A<sub>2</sub> showcased reductions by percentage effects of (75.6%, 74.5%, 32.1%, 63.7%, 49.3%, and 47.0%) for Pb, Cd, Ni, Co, Cr, and polyphenols, respectively compared to B. Meanwhile, A<sub>3</sub> displayed the most significant reductions, with percentage effects of (83.4%, 84.6%, 46.6%, 65.5%, 56.7%, and 76.0%) for Pb, Cd, Ni, Co, Cr, and polyphenols, respectively compared to B. Considering the provided information, the average percentage of effect for heavy metals and polyphenols was as follows: A<sub>1</sub> recorded a percentage effect of (38.80%), A<sub>2</sub> demonstrated a percentage effect of (57.04%), and A<sub>3</sub> exhibited the most substantial percentage effect at (68.80%).

## DISCUSSION

The observed values of B in all tested parameters closely matched the referenced values, particularly those presented in the work of **Sayed *et al.* (2014)**. Across the board, there was a discernible reduction in all indicators, with A<sub>2</sub> exhibiting the least impact. This outcome was attributed to its role as a mediator between the less impactful A<sub>1</sub> and the more influential A<sub>3</sub>, as evidenced by the study results.

These findings resonate with the conclusions drawn by (**Zagklis *et al.*, 2013**), who identified anaerobic digestion, coagulation, and lime processes as the most effective in lowering organic content and minimizing environmental impact. Lime treatment, proposed as a cost-effective pretreatment method, emerged as a less expensive approach for mitigating the polluting effects of OMW. It's noteworthy,

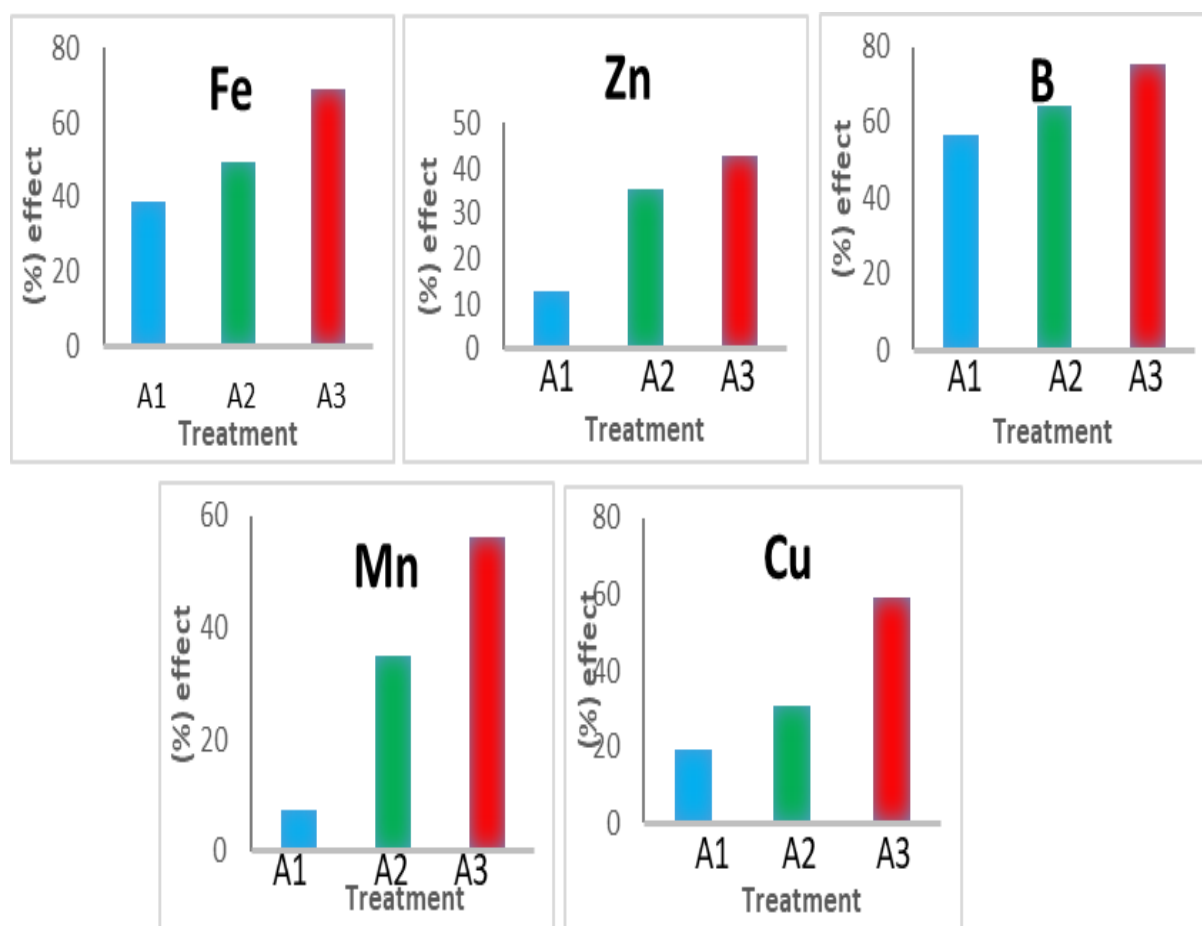


**Table 4. Effect of physical treatments on levels of micro nutrients in water samples of olive mill wastewater (OMW)**

Treatment	Fe (mg/L)	Zn (mg/L)	B (mg/L)	Mn (mg/L)	Cu (mg/L)
<b>B</b>	289.81 ±3.57a	22.06 ±0.54a	4.94 ±0.17a	10.20 ±0.095a	37.0 ±0.29a
<b>A<sub>1</sub></b>	177.52 ±12.46b	19.24 ±0.53b	2.14 ±0.17b	9.44 ±0.45b	29.92 ±1.24b
<b>A<sub>2</sub></b>	147.03 ±7.618c	14.21 ±0.83c	1.76 ±0.11c	6.65 ±0.42c	25.70 ±0.57c
<b>A<sub>3</sub></b>	89.58 ±1.57d	12.65 ±0.66d	1.23 ±0.06d	4.46 ±0.58d	15.06 ±1.40d

Results are means ± standard deviation for each analyzed parameter, a randomized complete block design (RCBD) with 12 samples and 3 replicates were used, same letters are not significantly ( $P < 0.05$ ) different according to the DMR test.

**B** (Raw olive mill wastewater), **A<sub>1</sub>** (Primary treatment), **A<sub>2</sub>** (Secondary treatment), **A<sub>3</sub>** (Advanced treatment), **Fe** (Iron), **Zn** (Zinc), **B** (Boron), **Mn** (Manganese), **Cu** (Copper), % effect (percentage effect).

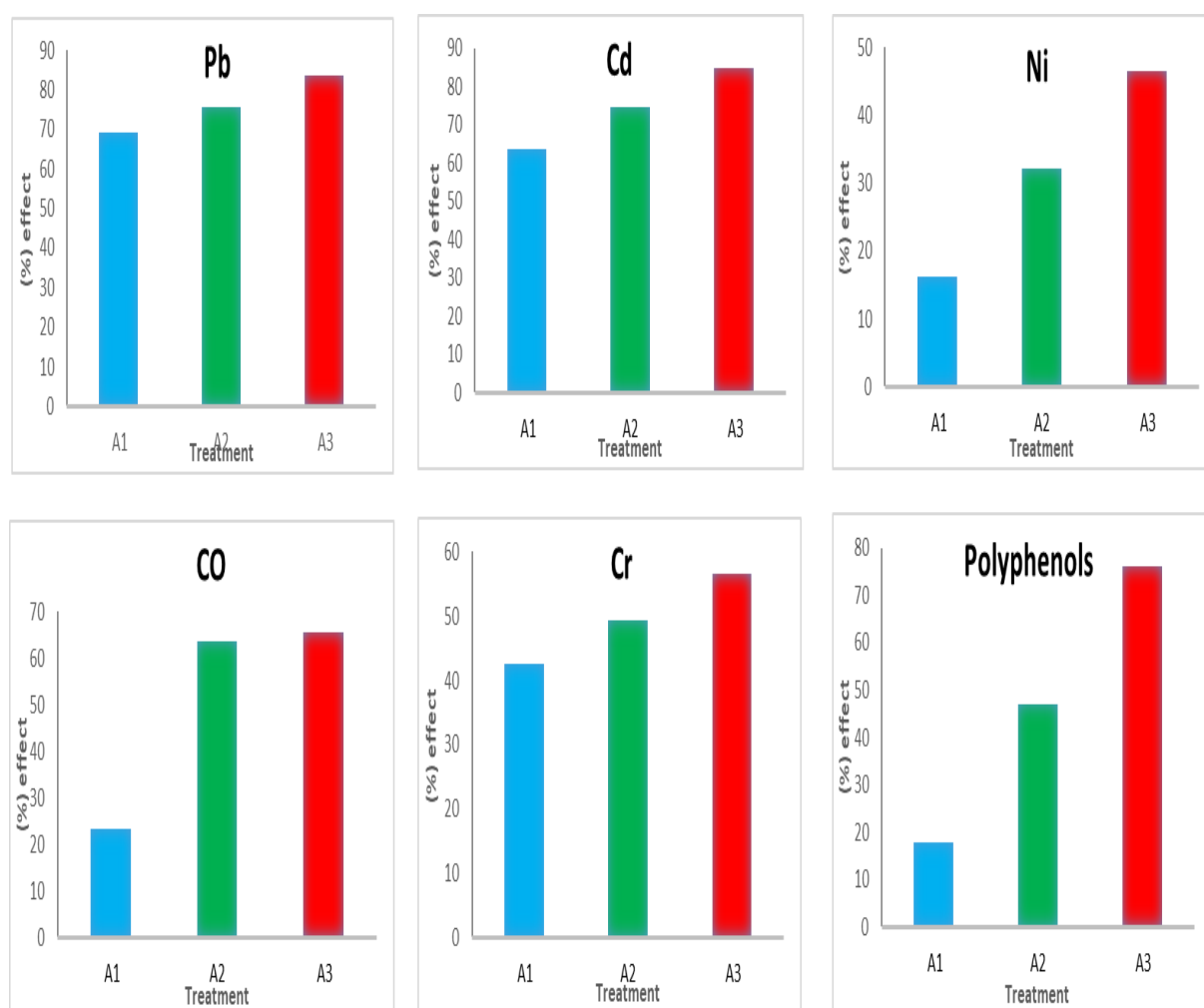
**Fig. 4. Percentage effect of physical treatments on levels of micro nutrients in water samples of olive mill wastewater (OMW)**

**Table 5. Effect of physical treatments on levels of heavy metals and polyphenols in water samples of olive mill wastewater (OMW)**

Treatment	Pb (mg/L)	Cd (mg/L)	Ni (mg/L)	Co (mg/L)	Cr (mg/L)	Polyphenols (g/L)
<b>B</b>	20.54 ±0.34a	2.47 ±0.51a	0.760 ±0.02a	2.26 ±0.35a	1.50 ±0.1a	9.466 ±0.62a
<b>A<sub>1</sub></b>	6.35 ±0.22b	0.90 ±0.056b	0.636±0.06b	1.73 ±0.12b	0.86 ±0.03b	7.790 ±0.82b
<b>A<sub>2</sub></b>	5.01 ±0.55c	0.63 ±0.02bc	0.516±0.01c	0.82 ±0.15c	0.76 ±0.15b	5.020 ±0.40c
<b>A<sub>3</sub></b>	3.40 ±0.21d	0.38 ±0.026c	0.406 ±0.02d	0.78 ±0.05c	0.65 ±0.16b	2.273 ±0.09d

Results are means ± standard deviation for each analyzed parameter, a randomized complete block design (RCBD) with 12 samples and 3 replicates were used, same letters are not significantly ( $P < 0.05$ ) different according to the DMR test.

**B** (Raw olive mill wastewater), **A<sub>1</sub>** (Primary treatment), **A<sub>2</sub>** (Secondary treatment), **A<sub>3</sub>** (Advanced treatment), **Pb** (Lead), **Cd** (Cadmium), **Ni** (Nickel), **Co** (Cobalt), **Cr** (Chromium), **% effect** (percentage effect).

**Fig. 5. Percentage effect of physical treatments on levels of heavy metals and polyphenols in water samples of olive mill wastewater (OMW)**

however, that the use of lime as the sole coagulant agent resulted in the generation of a substantial amount of sludge, peaking at 69.9% (**Fakhfakh *et al.*, 2024**). This underscores the importance of considering the downstream implications of such treatments.

In the specific case of the study, employing  $\text{Ca}(\text{OH})_2$  (treatment A<sub>2</sub>) as a reference coagulant yielded results consistent with earlier studies by **Zouari (1998)** and **Aktas *et al.* (2001)**. These findings were further substantiated by the works of **Sarika *et al.* (2005)**, **El Hajjouji *et al.* (2008)**, **Kilic and Solmaz (2013)**, **Barbera *et al.* (2013)** and more recently, **Sayed *et al.* (2014)** and **El-Sonbati *et al.* (2020)**.

The application of G.A.C treatment as an adsorbent agent (A<sub>3</sub>) aligned with prior research by **Mohan and Singh (2002)**, **Mavros *et al.* (2008)** and **Shabana *et al.* (2010)** and others, affirming the efficacy of this concept. These findings were consistently supported by **Chouchene *et al.* (2012)**, **Kilic and Solmaz (2013)**, **Barbera *et al.* (2013)**, **Sayed *et al.* (2014)** and more recently, **Annab *et al.* (2019)**.

The comprehensive results of the study showcased a noteworthy decrease in various physiochemical parameters (Turbidity, DO, COD, BOD, TSS, TDS) as detailed in Table 1. This reduction extended to heavy metals and polyphenols, as evidenced in Table 5. (**Mekki *et al.*, 2013**) demonstrated a similar decrease in COD and BOD in treated water, along with reductions in cations, anions, microelements, heavy metals, and polyphenols (Tables 2, 3, 4 and 5).

Consistent agreement with the results of the study was found in the works of **Chatzisyneon *et al.* (2013)**, **Al-Shaweesh *et al.* (2018)** and **Libutti *et al.* (2018)**. Furthermore, the importance of pretreatment for reducing costs in advanced purification techniques was underscored by **Ochando-Pulido and Crossmark (2012)** and **Ochando-Pulido and Ferez (2015)**.

Bioremediation, exemplified by **Salman *et al.* (2014)**, exhibited effectiveness in lowering phenols by 60% after a 2-week period. **Lanza *et al.* (2020)** emphasized the significance of OMW as a source of macro and micro-nutrients, aligning with **Zema *et al.* (2019)** and **Okur *et al.* (2020)** shared a similar perspective, considering that the water volume should not exceed 200 m<sup>3</sup>/h/y. A more detailed examination revealed that the concentration of heavy metals in all treatments remained within safe limits, adhering to the standards reported by **WHO/FAO (2007)** and **USEPA (2012)**.

## Conclusion

In conclusion, this study aimed to evaluate the impact of various physical treatments on Olive Mill Wastewater (OMW) treatment. The experimental system involved different stages, starting with primary treatment for the removal of large suspended particles, followed by secondary treatment for eliminating remaining dissolved organic matter, and finally advanced physicochemical treatment using granular activated carbon (G.A.C) as an adsorbent.

The results indicated that all treatments (A1, A2, A3) led to improvements in the physical and physicochemical characteristics of treated Olive Mill Wastewater (OMW), highlighting their effectiveness in enhancing the water quality. Advanced treatment stages demonstrated a greater effect in reducing harmful and pollutant concentrations. Statistical analysis supported the significance of these effects, endorsing the use of such treatments as environmentally friendly and effective alternatives for managing Olive Mill Wastewater.

The observed outcomes align with referenced studies and established methodologies, emphasizing the role of lime, coagulation, and G.A.C treatment in reducing organic content and minimizing environmental impact. However, the study underscores the importance of considering

potential challenges, such as sludge generation in lime treatment, to ensure sustainable and environmentally responsible wastewater management practices.

In summary, the comprehensive results showcased a significant decrease in various physiochemical parameters, including turbidity, dissolved oxygen, chemical oxygen demand, biochemical oxygen demand, total suspended solids, and total dissolved solids. This reduction also extended to heavy metals and polyphenols, demonstrating the efficacy of the employed treatments. Consistent agreement with other research studies further supports the findings, emphasizing the importance of pretreatment for cost reduction in advanced purification techniques.

## REFERENCES

- AbdelRahman, M.A. (2023).** An overview of land degradation, desertification and sustainable land management using GIS and remote sensing applications. *Rendiconti Lincei. Scienze Fisiche e Naturali*, 1-42.
- Abuzaid, A.S.; AbdelRahman, M.A.; Fadl, M.E. and Scopa, A. (2021).** Land degradation vulnerability mapping in a newly-reclaimed desert oasis in a hyper-arid agro-ecosystem using AHP and geospatial techniques. *Agron.*, 11 (7): 1426.
- Abou-Zaid, F.O.F. (2021).** Olive oil and rural development in Egyptian deserts. In *Management and development of agricultural and natural resources in Egypt's desert*. Cham: Springer Int. Publish., 451-490.
- Aktas, E.S.; Imre, S. and Ersoy, L. (2001).** Characterization and lime treatment of olive mill wastewater. *Water Res.*, 35 (9): 2336-2340.
- Al-Qodah, Z.; Al-Zoubi, H.; Hudaib, B.; Omar, W.; Soleimani, M.; Abu-Romman, S. and Frontistis, Z. (2022).** Sustainable vs. conventional approach for olive oil wastewater management: a review of the state of the art. *Water*, 14 (11): 1695.
- Al-Shaweesh, M.; Mohammed, M.; Al-Kabariti, D.; Khamash, D.; Al-Zawaidah, S.; Hindiyeh, M. and Omar, W. (2018).** Olive mill wastewater (OMW) treatment by using ferric oxide dephenolization and chemical oxygen demand removal. *Glob NEST J.*, 20: 558-563.
- Annab, H.; Fiol, N.; Villaescusa, I. and Essamri, A. (2019).** A proposal for the sustainable treatment and valorisation of olive mill wastes. *J. Environ. Chem. Eng.*, 7 (1): 102803.
- ASTM (2002).** American Standard for Testing Methods
- Barbera, A.C.; Maucieri, C.; Cavallaro, V.; Ioppolo, A. and Spagna, G. (2013).** Effects of spreading olive mill wastewater on soil properties and crops, a review. *Agric. Water Manag.*, 119: 43-53.
- Cecchi, L.; Bellumori, M.; Cipriani, C.; Mocali, A.; Innocenti, M.; Mulinacci, N. and Giovannelli, L. (2018).** A two-phase olive mill by-product (pâté) as a convenient source of phenolic compounds: Content, stability, and antiaging properties in cultured human fibroblasts. *J. Functional Foods*, 40, 751-759.
- Chatzistathis, T.; Kavvadias, V.; Sotiropoulos, T. and Papadakis, I.E. (2021).** Organic fertilization and tree orchards. *Agric.*, 11 (8): 692.
- Chatzisyneon, E.; Foteinis, S.; Mantzavinos, D. and Tsoutsos, T. (2013).** Life cycle assessment of advanced oxidation processes for olive mill wastewater treatment. *J. Clean. Prod.*, 54: 229-234.
- Chouchene, A.; Jeguirim, M.; Favre-Reguillon, A.; Trouvé, G.; Le Buzit, G.; Khiari, B. and Zagrouba, F. (2012).** Energetic valorisation of olive

- mill wastewater impregnated on low cost absorbent: Sawdust versus olive solid waste. *Energy*, 39(1): 74-81.
- Dolan, F.; Lamontagne, J.; Link, R.; Hejazi, M.; Reed, P. and Edmonds, J. (2021).** Evaluating the economic impact of water scarcity in a changing world. *Nature Commun.*, 12 (1) : 1915.
- Domingues, E.; Fernandes, E.; Gomes, J.; Castro-Silva, S. and Martins, R.C. (2021).** Olive oil extraction industry wastewater treatment by coagulation and Fenton's process. *J. Water Proc. Eng.*, 39: 101818.
- Duncan, D. B. (1958).** Multiple range and multiple F tests. *Biometrics*, 11(1): 1-42.
- El Hajjouji, H.; Baddi, G.A.; Yaacoubi, A.; Hamdi, H.; Winterton, P.; Revel, J.C. and Hafidi, M. (2008).** Optimisation of biodegradation conditions for the treatment of olive mill wastewater. *Biores. Technol.*, 99 (13): 5505-5510.
- El-Sonbati, M.A.; El-Battrawy, O.; Elawadly, E. and Hegazy, T. (2020).** Pretreatment of high organic load dairy industry wastewater by chemical coagulation and advanced oxidation processes. *Catrina: Int. J. Environ. Sci.*, 21 (1): 53-60.
- Fakhfakh, F.; Raissi, S.; Kriaa, K.; Maatki, C.; Kolsi, L. and Hadrich, B. (2024).** Modeling and optimization of a green process for olive mill wastewater Treatment. *Water*, 16 (2): 327.
- Foti, P.; Romeo, F.V.; Russo, N.; Pino, A.; Vaccaluzzo, A.; Caggia, C. and Randazzo, C.L. (2021).** Olive mill wastewater as renewable raw materials to generate high added-value ingredients for agro-food industries. *Appl. Sci.*, 11 (16): 7511.
- Khalil, J.; Habib, H.; Alabboud, M. and Mohammed, S. (2021).** Olive mill wastewater effects on durum wheat crop attributes and soil microbial activities: A pilot study in Syria. *Energy, Ecol. and Environ.*, 6: 469-477.
- Kilic, M.Y. and Solmaz, S.A. (2013).** Treatment alternatives of olive mill wastewater (OMW): A Review. *J. Selcuk Univ. Nat. and Appl. Sci.*, 279-290.
- Lanza, B.; Di Serio, M.G. and Di Giovacchino, L. (2020).** Microbiological and chemical modifications of soil cultivated with grapevine following agronomic application of olive mill wastewater. *Water, Air and Soil Pollution*, 231 (2): 86.
- Leontopoulos, S.; Skenderidis, P. and Vagelas, I.K. (2020).** Potential use of polyphenolic compounds obtained from olive mill wastewaters on plant pathogens and plant parasitic nematodes. *Plant Defence: Biol. Control*, 137-177.
- Libutti, A.; Gatta, G.; Gagliardi, A.; Vergine, P.; Pollice, A.; Beneduce, L. and Tarantino, E. (2018).** Agro-industrial wastewater reuse for irrigation of a vegetable crop succession under Mediterranean conditions. *Agric. Water Manag.*, 196: 1-14.
- Magdich, S.; Rouina, B.B. and Ammar, E. (2020).** Olive mill wastewater agronomic valorization by its spreading in olive grove. *Waste and Biomass Valoriz.*, 11: 1359-1372.
- Martins, D.; Martins, R.C. and Braga, M.E. (2021).** Biocompounds recovery from olive mill wastewater by liquid-liquid extraction and integration with Fenton's process for water reuse. *Environ. Sci. and Poll. Res.*, 28: 29521-29534.
- Mavros, M.; Xekoukoulotakis, N.P.; Mantzavinos, D. and Diamadopoulos, E. (2008).** Complete treatment of olive pomace leachate by coagulation, activated-carbon adsorption and electrochemical oxidation. *Water Res.*, 42 (12): 2883-2888.

- Mekki, A.; Dhoub, A. and Sayadi, S. (2013).** Effects of olive mill wastewater application on soil properties and plants growth. *Int. J. Recycling of Organic Waste in Agric.*, 2: 1-7.
- Mohan, D. and Singh, K.P. (2002).** Single-and multi-component adsorption of cadmium and zinc using activated carbon derived from bagasse-an agricultural waste. *Water Res.*, 36 (9): 2304 - 2318.
- Moustafa, A.A.; Elganainy, R.A. and Mansour, S.R. (2023).** Insights into the UNSG announcement: The end of climate change and the arrival of the global boiling era, July 2023 confirmed as the hottest month recorded in the past 120,000 years. *Catrina: Int. J. Environ. Sci.*, 28 (1): 43-51.
- Nunes, M.A.; Costa, A.S.; Bessada, S.; Santos, J.; Puga, H.; Alves, R.C. and Oliveira, M.B.P. (2018).** Olive pomace as a valuable source of bioactive compounds: A study regarding its lipid- and water-soluble components. *Sci. Total Environ.*, 644: 229-236.
- Ochando-Pulido, J.M. and Martinez-Ferez, A. (2012).** A focus on pressure-driven membrane technology in olive mill wastewater reclamation: State of the art. *Water Sci. and Technol.*, 66 (12): 2505-2516.
- Ochando-Pulido, J.M. and Martinez-Ferez, A. (2015).** On the recent use of membrane technology for olive mill wastewater purification. *Membranes*, 5 (4): 513-531.
- Okur, N.; Kayikçioğlu, H.H.; Okur, İ.B.; Yağmur, B.; Sponza, D.T. and Kara, R.S. (2020).** A study of olive mill wastewaters obtained from different treatment processes effects on chemical and microbial properties of a Typical Xerofluent soil and wheat yield. *Turk. J. Agric. and Forestry*, 44 (2): 140-155.
- Rocha, J.; Carvalho-Santos, C.; Diogo, P.; Beça, P.; Keizer, J.J. and Nunes, J.P. (2020).** Impacts of climate change on reservoir water availability, quality and irrigation needs in a water scarce Mediterranean region (southern Portugal). *Sci. Total Environ.*, 736: 139477.
- Rosa, L.; Chiarelli, D.D.; Rulli, M.C.; Dell'Angelo, J. and D'Odorico, P. (2020).** Global agricultural economic water scarcity. *Sci. Adv.*, 6 (18): eaaz 6031.
- Salman, M.; Abu-Khalaf, N.; Abu Rumaileh, B.; Jawabreh, M. and Abuamsha, R. (2014).** Detoxification of olive mill wastewater using the white rot fungus *Phanerochaete chrysosporium*. *Int. J. Environ. and Sustainab.*, 3 : 1.
- Sarika, R.; Kalogerakis, N. and Mantzavinos, D. (2005).** Treatment of olive mill effluents: part II. Complete removal of solids by direct flocculation with poly-electrolytes. *Environ. Int.*, 31 (2): 297-304.
- Sayed, H.F.; ElSebaay, A.A. and Abdelkarim, A.S. (2014).** Characteristics of some physiochemical factors for liquid wastewater treatments. *Sinai J. Appl. Sci.*, 3 (3): 93-102.
- Shabana, B.A.; El-Basiony, H.A.; Ahmed, M.Y. and El-Sebaae, K.A. (2010).** Pretreatment and elimination of toxicants from industrial wastewaters (Master's Thesis).
- Shabir, S.; Ilyas, N.; Saeed, M.; Bibi, F.; Sayyed, R.Z. and Almalki, W.H. (2023).** Treatment technologies for olive mill wastewater with impacts on plants. *Environ. Res.*, 216: 114399.
- Shabir, S.; Ilyas, N.; Ahmad, M.S.; Al-Ansari, M.M.; Al-Humaid, L. and Reddy, M.S. (2022).** Designing of pretreatment filter technique for reduction of phenolic constituents from olive-mill wastewater and testing its

- impact on wheat germination. *Chem.*, 299: 134438.
- Silvestri, L.; Forcina, A.; Di Bona, G. and Silvestri, C. (2021).** Circular economy strategy of reusing olive mill wastewater in the ceramic industry: How the plant location can benefit environmental and economic performance. *J. Clean. Prod.*, 326: 129388.
- Sygouni, V.; Pantziaros, A.G.; Iakovidis, I.C.; Sfetsa, E.; Bogdou, P.I.; Christoforou, E.A. and Paraskeva, C.A. (2019).** Treatment of two-phase olive mill wastewater and recovery of phenolic compounds using membrane technology. *Membranes*, 9 (2): 27.
- Tufariello, M.; Durante, M.; Veneziani, G.; Taticchi, A.; Servili, M.; Bleve, G. and Mita, G. (2019).** Patè olive cake: Possible exploitation of a by-product for food applications. *Frontiers in Nutr.*, 6:3.
- Tundis, R.; Conidi, C.; Loizzo, M.R.; Sicari, V. and Cassano, A. (2020).** Olive mill wastewater polyphenol-enriched fractions by integrated membrane process: A promising source of antioxidant, hypolipidemic and hypoglycaemic compounds. *Antiox.*, 9 (7): 602.
- Ungureanu, N.; Vladut, V. and Volcu, G. (2020).** Water scarcity and wastewater reuse in crop irrigation. *Sustainability*, 12 (21): 9055.
- United States Environmental Protection Agency (2012).** Guidelines for water reuse 600/R 12/618. Washington, DC, USA: USEPA.
- World Health Organization/Food and Agriculture Organization. (2007).** Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission 13th Session. Report of the Thirty Eight Session of the Codex Committee on Food Hygiene. Houston, TX, ALINORM 07/30/13.
- Wu, S.; Liu, L.; Li, D.; Zhang, W.; Liu, K.; Shen, J. and Zhang, L. (2023).** Global desert expansion during the 21<sup>st</sup> century: Patterns, predictors, and signals. *Land Degradation and Dev.*, 34 (2): 377-388.
- Zagklis, D.P.; Arvaniti, E.C.; Papadakis, V.G. and Paraskeva, C.A. (2013).** Sustainability analysis and benchmarking of olive mill wastewater treatment methods. *J. Chem. Technol. and Biotechnol.*, 88 (5): 742-750.
- Zema, D.A.; Lucas-Borja, M.E.; Andiloro, S.; Tamburino, V. and Zimbone, S.M. (2019).** Short-term effects of olive mill wastewater application on the hydrological and physico-chemical properties of a loamy soil. *Agric. Water Manag.*, 221, 312-321.
- Zouari, N. (1998).** Decolorization of olive oil mill effluent by physical and chemical treatment prior to anaerobic digestion. *J. Chem. Technol. and Biotechnol.: Int. Res. in Process, Environ., and Clean Technol.*, 73 (3): 297-303.

## الملخص العربي

### إدارة فعالة وقابلة للتنفيذ وعملية لمياه صرف معاصر الزيتون

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أجريت هذه الدراسة بهدف تقييم تأثير مختلف المعالجات الفيزيائية على مياه معالجة زيت الزيتون (OMW)، حيث تم جمع OMW من مصنع لزيت الزيتون وتخزينها في خزان من الخرسانة غير المغطى. تم تخفيفها بالماء قبل البدء في التجربة. تم تنفيذ مراحل مختلفة من المعالجة بدءاً من المعالجة الأولية (الفيزيائية) لإزالة الجسيمات الكبيرة والعائمة، ومروراً بالمعالجة الثانوية (الفيزيوكيميائية) لإزالة المواد العضوية المذابة، وصولاً إلى المعالجة المتقدمة باستخدام الكربون النشط. تمت متابعة التأثير على الصفات الفيزيائية والفيزيوكيميائية للمياه، بما في ذلك الحموضة، التوصيل الكهربائي، والعكارة، والمواد العضوية المذابة، والأملاح الكلية. تم أيضاً قياس تأثير المعالجات على مستويات الكاتيونات (الصوديوم، البوتاسيوم، الكالسيوم، المغنيسيوم) والأنيونات (كربونات، هيدروكربونات، كلوريد، كبريتات، فوسفات، نترات، والمغذيات الصغرى (الحديد، الزنك، النحاس، المنجنيز، البورون)، المعادن الثقيلة (الرصاص، الكاديوم، النيكل، الكوبالت، الكروم) والبوليفينولات في المياه. أظهرت النتائج أن جميع المعالجات ( $A_1, A_2, A_3$ ) قد أدت إلى تحسينات في الصفات الفيزيائية والفيزيوكيميائية، مما يشير إلى فعاليتها في تحسين جودة مياه معالجة زيت الزيتون. المراحل المتقدمة من المعالجة أظهرت تأثيراً أكبر في تقليل تركيز المواد الضارة والملوثة. يشير التحليل الإحصائي إلى أن التأثيرات كانت ملحوظة وتدعم استخدام هذه المعالجات كبديل فعالة وصديقة للبيئة لإدارة مياه معالجة زيت الزيتون.

**الكلمات الإسترشادية:** التغيير المناخي، مياه صرف معاصر الزيتون، ندرة المياه، إدارة المياه المستدامة، كفاءة معالجة.

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