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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^{-1} and 35–110 g L^{-1}, 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_1.

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 $Ca(OH)_2$ as a coagulant (60g/100 L), labeled as A_2.

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_3.

Physical and Chemical (Physiochemical) 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^+, K^+, Ca^{+2}, Mg^{+2}), anions (CO_3^{-2}, HCO_3^-, Cl^-, SO_4^{-2}, PO_4^{-3}, NO_3^-), 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_1 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_1 (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_1 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^1)	Turbidity (NTU)	D.O (mg/L)	COD (g/L)	BOD (g/L)	TSS (g/L)	TDS (g/L)
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
A_1	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
A_2	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
A_3	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_1** (Primary treatment), **A_2** (Secondary treatment), **A_3** (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).

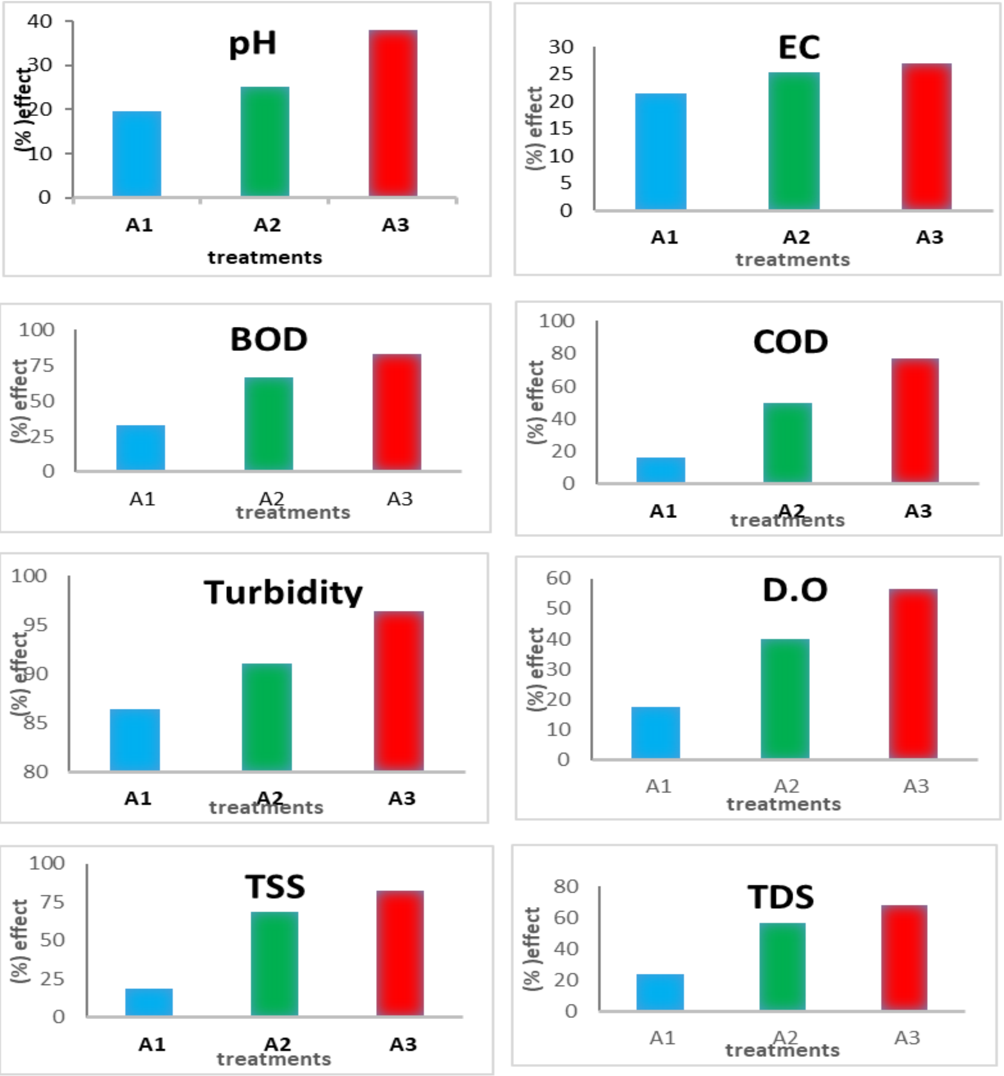

Fig. 1. Percentage effect of physical treatments on physiochemical characteristics in water samples of olive mill wastewater (OMW)

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$^+$ (mg/L)	K$^+$ (mg/L)	Ca$^+$ (mg/L)	Mg$^+$ (mg/L)
B	49.48 ±0.89a	11.10 ±0.77a	13.35 a ±0.53a	13.32 a ±0.56a
A$_1$	38.01 ±0.18b	9.02 ±0.49b	9.52 c±0.87b	10.59 ±0.15b
A$_2$	34.38 ±0.60c	6.97 ±0.38c	7.72 d±0.76c	8.50 ±0.19c
A$_3$	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$_1$** (Primary treatment), **A$_2$** (Secondary treatment), **A$_3$** (Advanced treatment), **Na$^+$** (Sodium), **K$^+$** (Potassium), **Ca+** (Calcium), **Mg$^+$** (Magnesium), **% effect** (percentage effect).

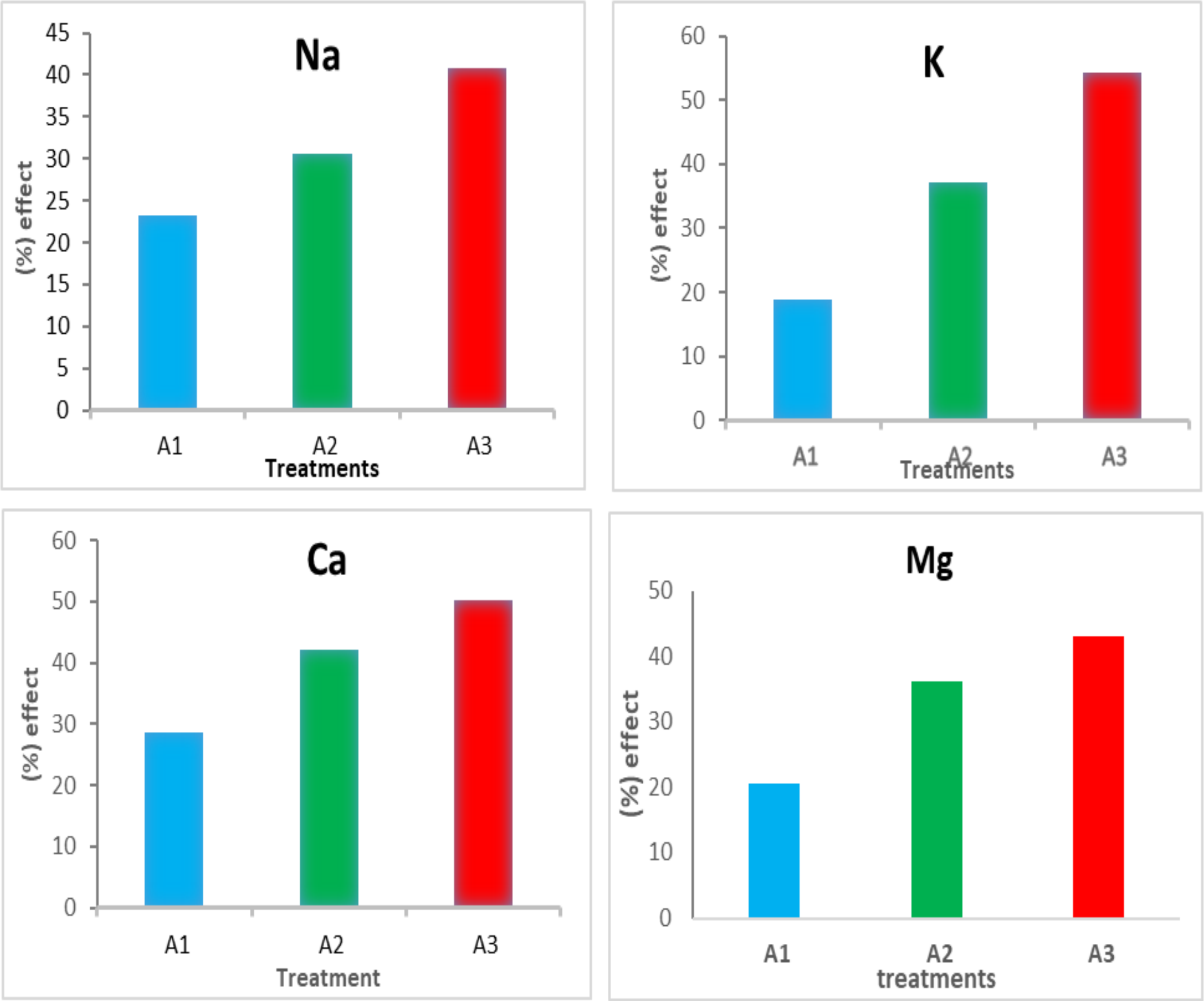

Fig. 2. Percentage effect of physical treatments on levels of macro nutrients (cations) in water samples of olive mill wastewater (OMW)

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

Treatment	HCO_3^{-2} (mg/L)	Cl^- (mg/L)	SO_4^{-2} (mg/L)	PO_4^{-3} (mg/L)	NO_3^- (mg/L)	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_1	27.67 ±0.40b	26.54 ±0.16ab	25.41 ±0.22b	471.33 ±5.03b	549.66 ±3.51b	nd
A_2	26.60 ±0.19c	25.48 ±1.11b	23.64 ±0.17c	456.33 ±5.51c	464.66 ±12.66c	nd
A_3	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_1** (Primary treatment), **A_2** (Secondary treatment), **A_3** (Advanced treatment), **HCO_3^{-2}** (Bicarbonate), **Cl^-** (Chloride), **SO_4^{-2}** (Sulfate), **PO_4^{-3}** (Phosphate), **NO_3^-** (Nitrate), **CO_3^{-2}** (Carbonate), **% effect** (percentage effect), **nd** (non detected).

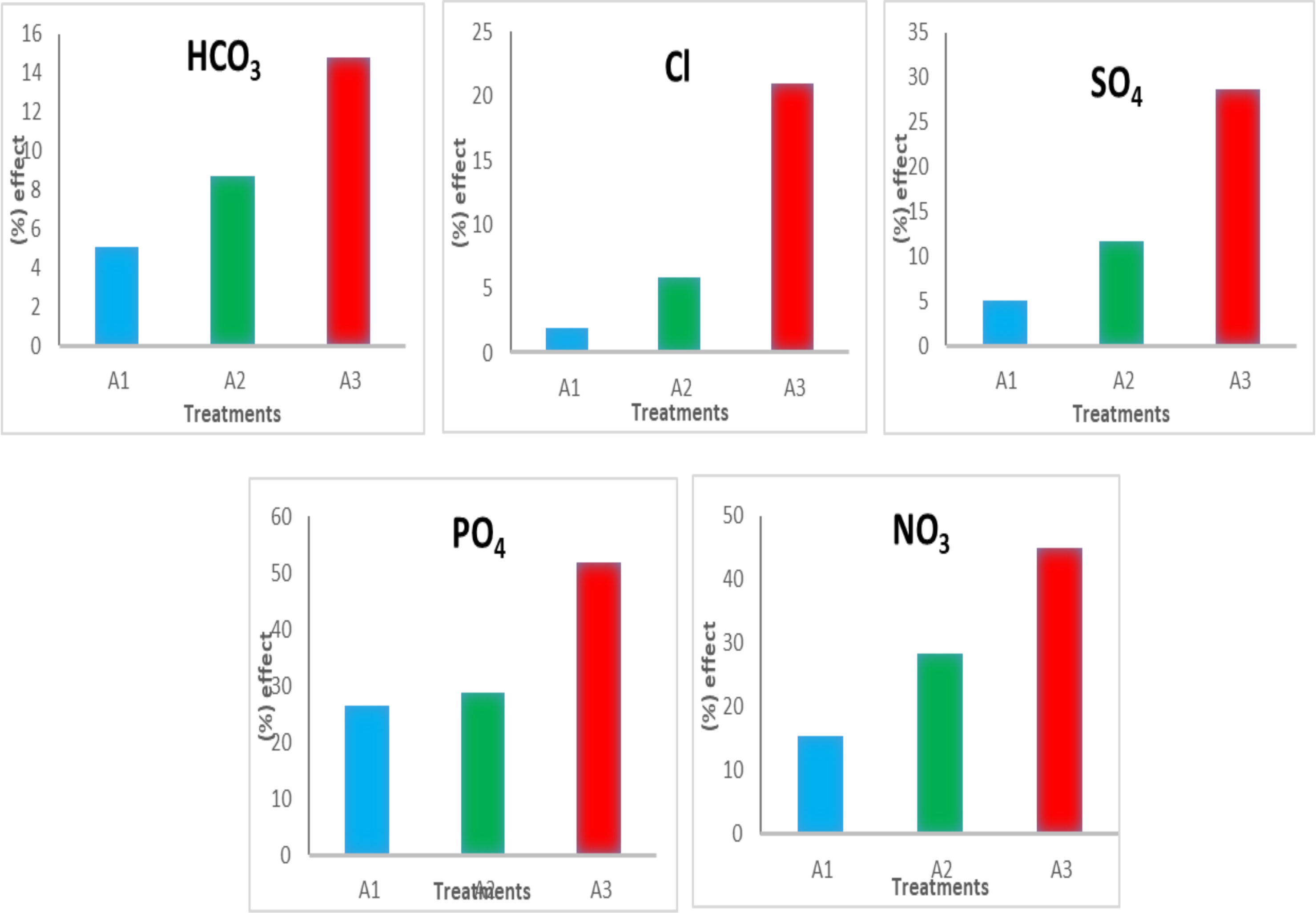

Fig. 3. Percentage effect of physical treatments on levels of macro nutrients (anions) in water samples of olive mill wastewater (OMW)

These findings imply that the concentrations of these macronutrients (anions) in the olive mill wastewater decreased noticeably as physical treatments advanced from A_1 to A_3, indicating the effectiveness of the treatments in changing the anionic composition of the water samples. $A_1<A_2<A_3$ 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_3^-, Cl^-, SO_4^{-2}, PO_4^{-3}, and NO_3^-).

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_1 to A_3, there were consistent reductions in the concentrations of these micronutrients. A_1 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_2 and A_3, demonstrated further declines in these micronutrient levels. A_2 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_3 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_1 recorded a percentage of impact of (26.99%), A_2 demonstrated a percentage of impact of (42.94%), and A_3 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_1 to A_3, there were consistent reductions in the concentrations of these parameters. A_1 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_2 and A_3, demonstrated further declines in these parameters.

A_2 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_3 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_1 recorded a percentage effect of (38.80%), A_2 demonstrated a percentage effect of (57.04%), and A_3 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_2 exhibiting the least impact. This outcome was attributed to its role as a mediator between the less impactful A_1 and the more influential A_3, 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	289.81 ±3.57a	22.06 ±0.54a	4.94 ±0.17a	10.20 ±0.095a	37.0 ±0.29a
A_1	177.52 ±12.46b	19.24 ±0.53b	2.14 ±0.17b	9.44 ±0.45b	29.92 ±1.24b
A_2	147.03 ±7.618c	14.21 ±0.83c	1.76 ±0.11c	6.65 ±0.42c	25.70 ±0.57c
A_3	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_1** (Primary treatment), **A_2** (Secondary treatment), **A_3** (Advanced treatment), **Fe** (Iron), **Zn (**Zinc), **B (**Boron), **Mn (**Manganese), **Cu** (Copper), **% effect** (percentage effect).

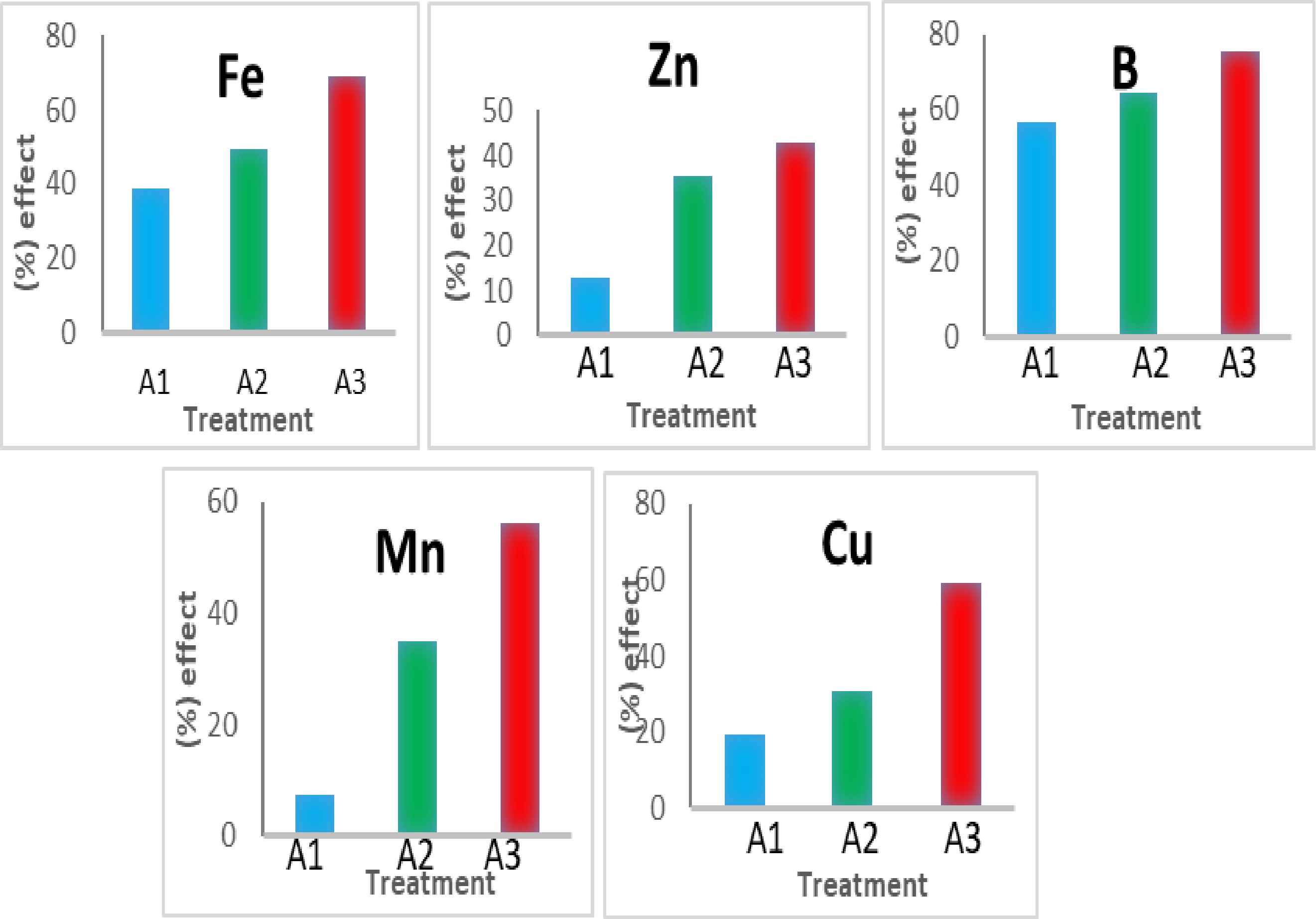

Fig. 4. Percentage effect of physical treatments on levels of micro nutrients in water samples of olive mill wastewater (OMW)

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	20.54 ±0.34a	2.47 ±0.51a	0.760 ±0.02a	2.26 ±0.35a	1.50 ±0.1a	9.466 ±0.62a
A_1	6.35 ±0.22b	0.90 ±0.056b	0.636±0.06b	1.73 ±0.12b	0.86 ±0.03b	7.790 ±0.82b
A_2	5.01 ±0.55c	0.63 ±0.02bc	0.516 ±0.01c	0.82 ±0.15c	0.76 ±0.15b	5.020 ±0.40c
A_3	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_1** (Primary treatment), **A_2** (Secondary treatment), **A_3** (Advanced treatment), **Pb** (Lead)**, Cd** (Cadmium)**, Ni** (Nickel)**, Co** (Cobalt)**, Cr** (Chromium), **% effect** (percentage effect).

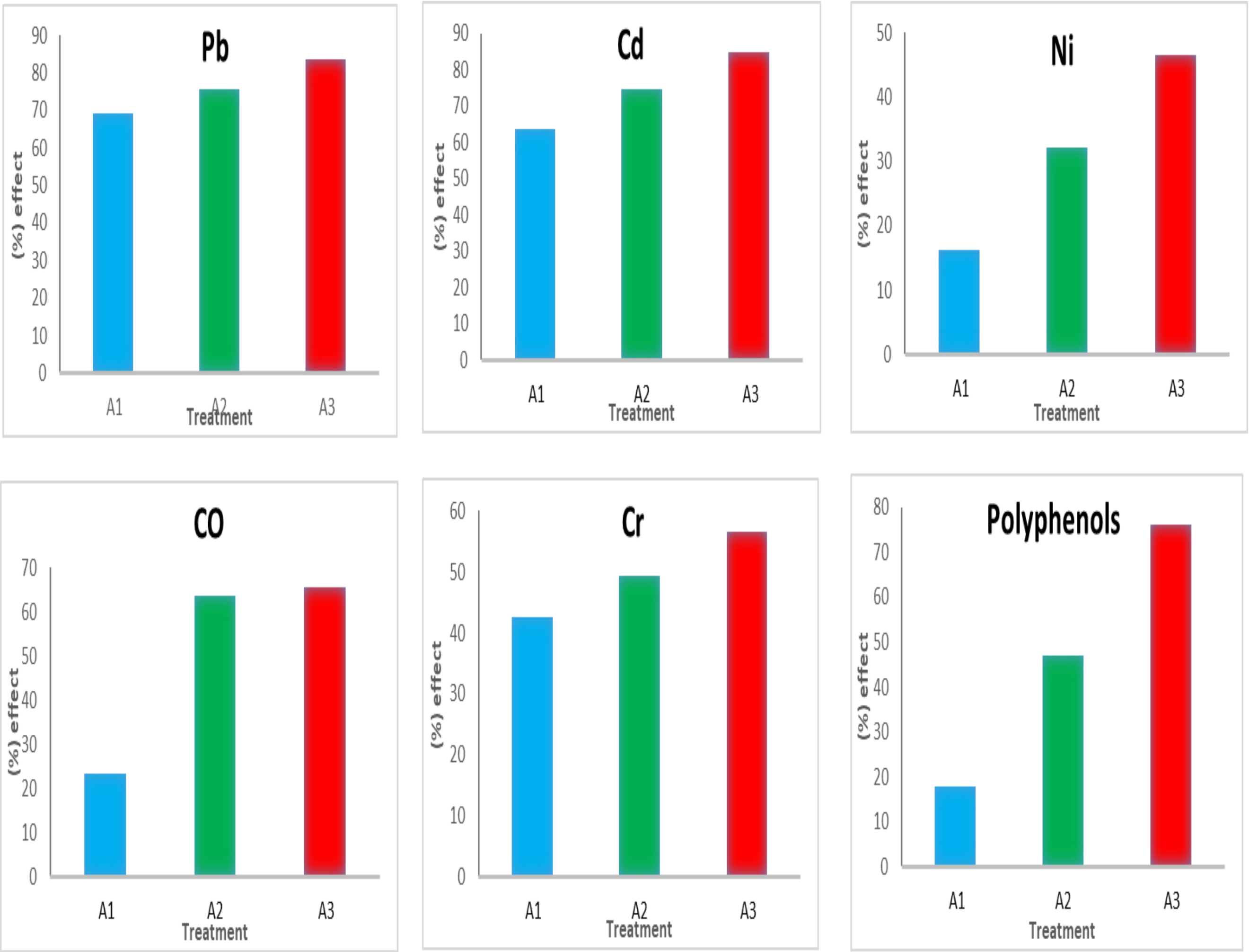

Fig. 5. Percentage effect of physical treatments on levels of heavy metals and polyphenols in water samples of olive mill wastewater (OMW)

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 $Ca(OH)_2$ (treatment A_2) 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_3) 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 **Chatzisymeon *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^3/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.

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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 بدءًا 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، الكادميوم، 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 تأثيرًا أكبر في تقليل تركيز المواد الضارة والملوثة. يشير التحليل الإحصائي إلى أن التأثيرات كانت ملحوظة وتدعم استخدام هذه المعالجات كبدائل فعالة وصديقة للبيئة لإدارة مياه معالجة زيت الزيتون.

الكلمات الإسترشادية: التغير المناخي، مياة صرف معاصر الزيتون، ندرة المياه، إدارة المياه المستدامة، كفاءة معالجة.

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