Date-Palm Waste Usage for Low-cost Advanced Treatment for Domestic Wastewater in Arid regions

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ABSTRACT: Arid countries suffer from the water shortage especially, with the recent high-water demand. It is crucial for governmental sectors and researchers to find a solution to this critical problem. This study introduces a possible solution through the reuse of treated wastewater. The proposed solution provides the reuse of the treated wastewater for unrestricted irrigation purposes. This solution also solves the problem of wastewater discharge into the environment and saves natural water resources. The work adopted a low-cost and advanced treatment method by using natural materials such as date-palm wastes. These wastes are abundant in arid countries and may introduce a problem also for their landfill. The study explored the possibility of using the date-palm waste as an absorbent material for the pollutants from domestic wastewater effluents. The research methodology relied on the experimental work on a lab scale. Leaching batch tests for this waste were adopted initially to evaluate its ions' extraction into water. Then its ability for the purification of wastewater effluents was investigated through an absorption mechanism. Various parameters were examined in both processes such as the liquid to solid ratio (L/S), initial pH, and material size. In addition, different types of palm wastes were studied such as wastes from leaves, stems, and trunks. The results of leaching tests showed in general a high rate of release of many ions into distillated water at different

conditions. Treatment results also exhibited a notable increase of element release into wastewater effluents. Prewashing and drying the coarse wastes before using them with wastewater demonstrated a promising ability for these wastes to remove many elements from wastewater.

KEYWORDS: Wastewater, Treatment, Palm Waste, Absorption, Leaching

استخدام مخلفات النخيل في المعالجة المتقدمة منخفضة التكلفة لمياه الصرف الصحي المنزلية في المناطق القاحلة

الملخص: تعاني البلدان القاحلة من نقص المياه بشكل خاص، مع ارتفاع الطلب على المياه في الآونة الأخيرة. ومن الأهمية بمكان للقطاعات الحكومية والباحثين إيجاد حل لهذه المشكلة الحرجة. تقدم هذه الدراسة حلاً ممكناً من خلال إعادة استخدام مياه الصرف الصحي المعالجة. يوفر الحل المقترح إعادة استخدام مياه الصرف الصحي المعالجة لأغراض الري غير المقيدة. كما يعمل هذا الحل على حل مشكلة تصريف مياه الصرف الصحي إلى البيئة وتوفير موارد المياه الطبيعية. اعتمد العمل على أسلوب معالجة منخفض التكلفة ومتقدم باستخدام المواد الطبيعية مثل مخلفات النخيل. وتتوافر هذه النفايات بكثرة في البلدان القاحلة وقد تسبب مشكلة أيضًا لمدافن النفايات الخاصة بها. بحثت الدراسة في إمكانية استخدام مخلفات النخيل كمادة ماصة للملوثات الناتجة عن مياه الصرف الصحي المنزلية. اعتمدت منهجية البحث على العمل التجريبي على نطاق مختبري. تم اعتماد اختبارات الترشيح لهذه النفايات في البداية لتقييم استخلاص أيوناتها في الماء. ومن ثم تم دراسة قدرتها على تنقية مياه الصرف الصحي من خلال آلية الامتصاص. تم فحص معلمات مختلفة في كلتا العمليتين مثل نسبة السائل إلى المادة الصلبة(L/S) ، ودرجة الحموضة الأولية، وحجم المادة. بالإضافة إلى ذلك تمت دراسة أنواع مختلفة من مخلفات النخيل مثل مخلفات الأوراق والسيقان والجذوع. أظهرت نتائج اختبارات الترشيح بشكل عام ارتفاع نسبة إطلاق العديد من الأيونات في الماء المقطر عند ظروف مختلفة. أظهرت نتائج المعالجة أيضًا زيادة ملحوظة في إطلاق العناصر في مياه الصرف الصحي السائلة. وأظهر الغسيل المسبق للمخلفات الخشنة وتجفيفها قبل استخدامها مع مياه الصرف الصحي قدرة واعدة لهذه المخلفات على إزالة العديد من العناصر من مياه الصرف الصحي.

1.INTRODUCTION

The whole world in general, as well as the Arab region, suffers from a shortage of freshwater sources for drinking, irrigation, and industrial activities. There are many areas in the Arab regions, especially in the Gulf countries, suffering from a great shortage of freshwater sources due to the lack of surface water resources. It is essential for these regions to manage and save the current available resources of freshwater [1]. The most reliable option for providing renewable freshwater is the treatment and reuse of wastewater. A huge amount of wastewater is generated annually and causes a problem of disposal in a safe way. Reuse wastewater will have a double positive impact by providing fresh water and solving its problem of disposal [2].

Treating and reusing wastewater as a source of freshwater is a challenging process as it needs applying advanced treatment methods after the basic treatment stages. These advanced methods are regularly expensive and energy consumption. Thus, intensive research is required to find low-cost and affectable methods for the advanced treatment of wastewater effluents. One of these promising low-cost methods is adopting adsorbent and absorbent materials in the purification of wastewater effluents. Various materials were examined as potential adsorbents. The adsorbents in general are classified into two categories: conventional and non-conventional. Conventional adsorbents such as alumina and zeolite were adopted at a minimal level. For the non-conventional, the most frequently used is agro-wastes. These wastes may introduce a good bio-adsorbent for wastewater treatment and introduce a good reuse for these wastes before disposal [3]. Abundant of date-palm wastes are generated annually, especially in the Middle East area. 100 million date-palm trees exist approximately around the world. In the Middle East and North Africa, 62 % of these trees are implanted. In the Kingdom of Saudi Arabia, for an instant, date-palm trees generate 1500 tons of waste materials from tree leaves. These wastes cause a great problem for their disposal and landfilling. They usually are stored in agricultural lands, or burned, which causes health and environmental problems [4]–[6]. However, on the other hand, they have the potential to work as a bio-adsorbent for many elements dissolved in wastewater effluents.

Earlier studies investigated the possibility of using date-palm wastes as an adsorbent for pollutants. Ahmed et al. [7] addressed an overall review on date-palm trees and their uses

as adsorbents for removing pollutants, heavy-metals and dyes from water and wastewater. Some studies concluded that date-palm waste can be used as adsorbents for the removal of unwanted materials from wastewater. Nujic et al. [8] showed that the use of date-palms for adsorption purposes in removing pollutants such as heavy-metals, dyes and phosphates from aquatic has succeeded. They reported also that the research on the date-palm fibers and their uses as bio adsorbents for the removal of pollutants from wastewater are limited to date. Their conclusion showed that the fibers of date-palms can be employed as low-cost adsorbents in removing pollutants from wastewater. Jonoobi et al. [9] conducted a general review on the applications of date-palm tree in Middle East countries. They concluded, as proven by some researchers, that the date-palm is used for many applications including removing of heavy-metals and soil fertilizing. Mohamed *et al.*[10] studied using a powder of date seeds (PADS) as an adsorbent in removing heavy metal ions such as cadmium, lead, copper, chromium, cobalt, and manganese from water. A mass of 0.1 gram of PADS was added to a volume of 50 mL of the water sample. The maximum removal efficiency was 93.34%, 71.06%, 92.06%, 96.96%, 95.91% and 36.13% for Cd2+, Cr3+, Co2+, Cu2+, Pb2+ and Mn2+ ions respectively. They argued that the findings of this study can be taken as a solution and baseline information for heavy metal removal in different applications.

In this work, the date-palm wastes were evaluated as a treatment tool for removing contaminations from domestic wastewater effluents to be suitable for irrigation. The study investigated different types of date-palm waste components such as leaves, branch-stems, and trunk-fibers. The examination included the leaching and absorption properties of these wastes. The research was based on experimental work on a lab scale. Many parameters were examined such as the material size, different components of date-palm wastes, liquid to solid ratio (L/S), initial pH, and impact of the prewashing and drying process on the waste materials.

2. MATERIALS AND METHODS

2.1 Materials

The date-palm wastes used in this research are available in the western of the Kingdom of Saudi Arabia (KSA) in Madinah governorate. Samples from leaves, branch-stem and trunk were collected from three locations. Part of the samples was grinded into a powder with a size of less than 1 mm and others were cut into small pieces with sizes ranging between 10 to 300 mm. The main chemical compositions of these wastes are like all agricultural wastes, which include cellulose, hemicelluloses, and lignin. They are mainly carbohydrate polymers [11].

2.2 Leaching Tests

To examine the components released from date-palm waste into treated domestic wastewater, the leaching tests were adopted following to British Standard procedure [12]. The waste materials were soaked without shaking or mixing in distilled water for 24 hours. TDS, turbidity pH, and hardness were observed for 24 hours. Then a water sample was collected directly without filtrations and chemically analyzed to determine the released ions from waste materials into the water. Many cations, anions, and heavy metals were measured. Several parameters were investigated including the liquid-to-solid (L/S) as 10 and 20, and three values of pH namely 4, 6, and 10. Finally, the waste materials were used in two size sets namely, fine materials by grinding the waste to a particle size of less than 1 mm and coarse materials by cutting the waste to a size ranging from 10 to 300 mm. These sizes were chosen based on the available cutting and grinding tools to represent coarse and fine materials.

2.3 Absorption Tests (Treatment Tests)

In these experiments, the date-palm waste was examined as a bio-absorbent for the impurities in the wastewater. The waste was soaked in the domestic wastewater effluent for up to 24 hours. The effluent is collected from the wastewater treatment plant at Al Madinah city, KSA. The effluent has two types namely, secondary, or biologically treated with aeration tanks (WII); and tertiary treated with sand filters (WIII). Besides previously

mentioned measurements in the leaching tests, BOD and COD were observed after 24 hours. Studied parameters in these experiments included examining the wastes with both WII and WIII samples individually. Furthermore, another test investigated the waste treatment ability by soaking the waste in distilled water for 24 hours and drying before adding it to WII. This is to reduce the leached ions from the solid waste into the water sample. Table 1 presents a summary of the studied parameters.

3. RESULTS AND DISCUSSION

3.1 Leaching Properties

The leaching and absorption processes are the most important interactions between solid and liquid. The absorption process is the opposite of the leaching process as in the latter the particles are extracted from solid materials into water and in the former the particles were held by the solid materials from water. Therefore, it is crucial to investigate the leaching properties of any solid materials intended to be used as absorbent. Thus, in this work, the leaching properties of the date-palm waste were investigated by studying several influenced parameters as described above.

Table 1: Details of Studied Parameters with Date-Palm Waste Samples.

Sample	Material Size/Status	Water	Initial pH	Liquid to Solid (L/s)	Test Symbol
WII	--	Secondary treated wastewater	Natural	10	WII
WIII	--	Tertiary treated wastewater	Natural	10	WIII
P1	Fine materials (<1 mm) from branch stem and leaves	Distilled water	6.0	10	F-S&L/D
P2	Fine materials (<1 mm) from trunk	Distilled water	6.0	10	F-T/D

P3	Fine materials (<1 mm) Mixture from branch stem, leaves and trunk	Distilled water	6.0	10	Mix-F/D
P4	Coarse materials (10 to 300 mm) Mixture from branch stem, leaves and trunk.	Distilled water	6.0	10	Mix-C/D
P5	Coarse materials (10 to 300 mm) Mixture from branch stem, leaves and trunk.	Distilled water	4.0	10	Mix/C/D/ pH=4
P6	Coarse materials (10 to 300 mm) Mixture from branch stem, leaves and trunk.	Distilled water	10.0	10	Mix/C/D/ pH=10
P7	Coarse materials (10 to 300 mm) Mixture from branch stem, leaves and trunk.	Distilled water	6.0	20	Mix/C/D/ pH=6/L/s =20
P8	Fine materials (<1 mm) Mixture from branch stem, leaves and trunk	Secondary treated wastewater	Natural	10	Mix-F/WII
P9	Coarse materials (10 to 300 mm) Mixture from branch stem, leaves and trunk.	Secondary treated wastewater	Natural	10	Mix-C/WII
P10	Fine materials (<1 mm) Mixture from branch stem, leaves and trunk	Tertiary treated wastewater	Natural	10	Mix-F/WIII
P11	Coarse materials (10 to 300 mm) Mixture from branch stem, leaves and trunk.	Tertiary treated wastewater	Natural	10	Mix-C/WIII
P12	Coarse materials (10 to 300 mm) Mixture from branch stem, leaves and trunk. (Prewashed and dried)	Secondary treated wastewater	Natural	10	Mix-C/WII-prewashed

P (palm sample); F (fine materials; C (coarse materials); S (stem); L (leave); T (trunk); D (distilled)

3.1.1 Physicochemical Characteristics

Figure 1 presents the results of TDS, hardness, turbidity, and pH measurements at 24 hours after adding date-palm waste to the distilled water for different parameters, P1 to P7. Samples from grinded branch stem and leaves, P1, showed less content of TDS and turbidity than those from grinded trunk, P2 or the mixture of all of them together as in P3. This perhaps due to ion exchange process. While P1 showed a slight increase in hardness and pH values. The coarse sample, P4 showed smaller values in general than fine the material samples. This confirms the fact that the release from waste as fine materials more than coarse sizes due to the increase in the surface area of the fine or grinded materials and consequently increase contact with liquid. The same results were reported by Altaher [11] who studied the impact of different particle sizes of agro-wastes on leaching properties. For initial pH values, results of TDS, hardness and pH showed an increase with increase initial pH values, samples P4 to P6, except for turbidity exhibited the highest value with a starting pH of 4. For the L/S ratio, comparing samples P7 to P4 having ratios of 20 and 10 respectively showed a decline in all properties with the increase in the ratio. This is perhaps due to reduce the mass of the solid waste in water. This agrees with results reported elsewhere [11].

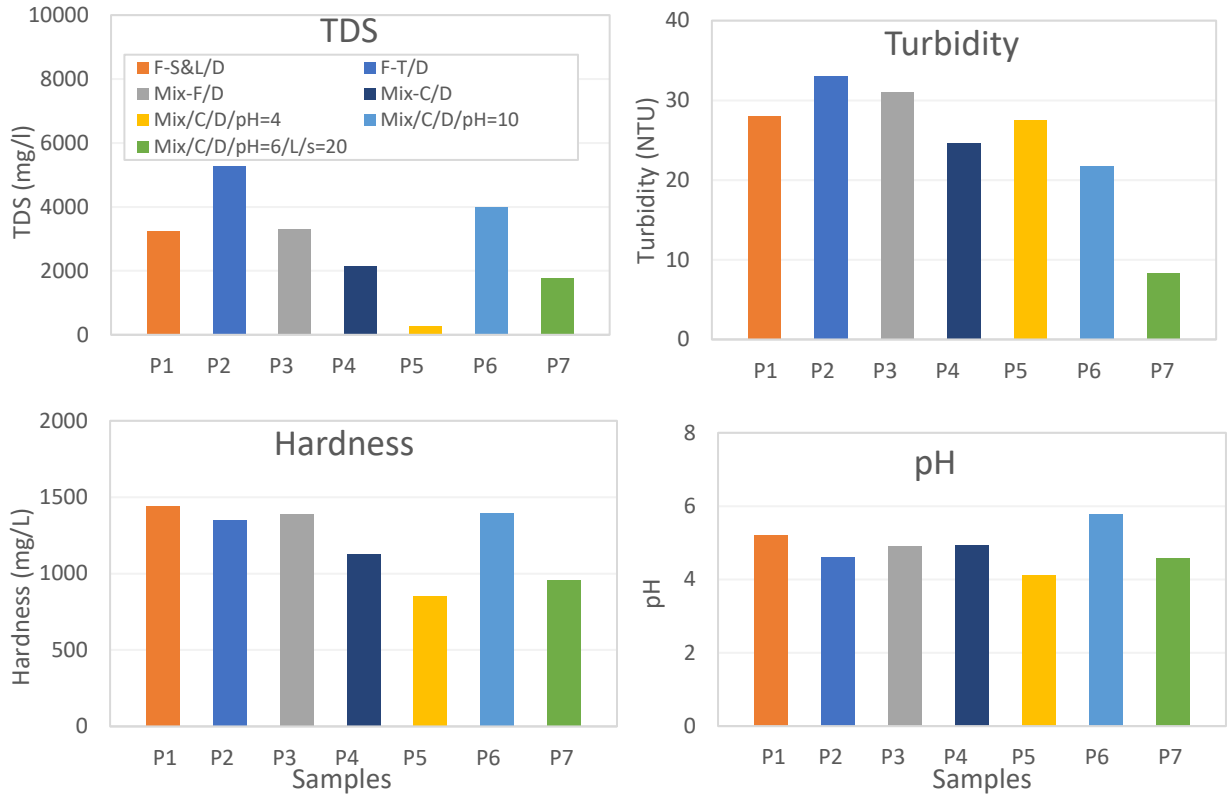


Figure 1: TDS, Hardness, Turbidity, and pH Results at 24 hours after Adding Date-Palm Waste to Distilled Water with Different Parameters.

3.1.2 Ions' Release

Many ions were investigated including cations such as K, Mg, Na, Ca, anions such as NO_3 and SO_4, and heavy metals extracted from the date-palm waste due to contact with water. Selected elements are presented in Figure 2. The results in general showed a high rate of element extraction into water. Sample P2, i.e., fine materials from the trunk, showed the highest rate of element release except for heavy metals such as iron, Fe, and copper, Cu. It seems, that this part of the palm tree does not have abundant content of metals while P1 from leaves showed higher levels of metal extraction. Coarse materials exhibited a lower rate of extraction than fine ones as seen from P4 and P3 results. For initial pH values, results of the release such as K, Mg, Na, Ca, and Fe showed an approximately decline with an increase in initial pH values except for Cu showed a slight increase of the extraction in alkalinity conditions, which is considered as an odd result. Dortwegt and Maughan [13] concluded that the solubility of cooper in water decreased with the increase of pH at different temperatures. The higher ratio of L/S demonstrated the less extraction as seen in sample P7 results. This is perhaps due to the dilution impact of increasing liquid

amount to solid. However, for Cu, the extraction of the element increased. Luo *et al.* [14] reported the same as they showed that the solubility of metals increases with the increase of liquid content.

3.2 Absorption Properties of the Date-Palm Waste

The absorption process is the treatment mechanism adopted in this work. The absorption ability of date-palm waste was examined with the wastewater effluents.

3.2.1 Physicochemical Characteristics

Results of TDS, hardness, turbidity, and pH measurements at 24 hours after adding date-palm waste to wastewater effluents with different parameters, i.e., samples WII, WIII and P8 to P12 are presented in Figure 3. All samples of the fine and coarse materials mixed from grinded branch-stems, leaves and trunk with secondary and tertiary treated wastewater, i.e., P8 to P11 demonstrated higher content of TDS, turbidity, and hardness than the reference samples of the secondary and tertiary treated wastewater, WII and WIII. Thus, still the prominent process here is leaching not absorption. The sample of the coarse materials mixed from cut branch-stems, leaves and trunk with the prewashing process, P12, revealed good improvement as it showed less content than all other samples. It demonstrates promising results for effective treatment as in this case, adding the waste into water

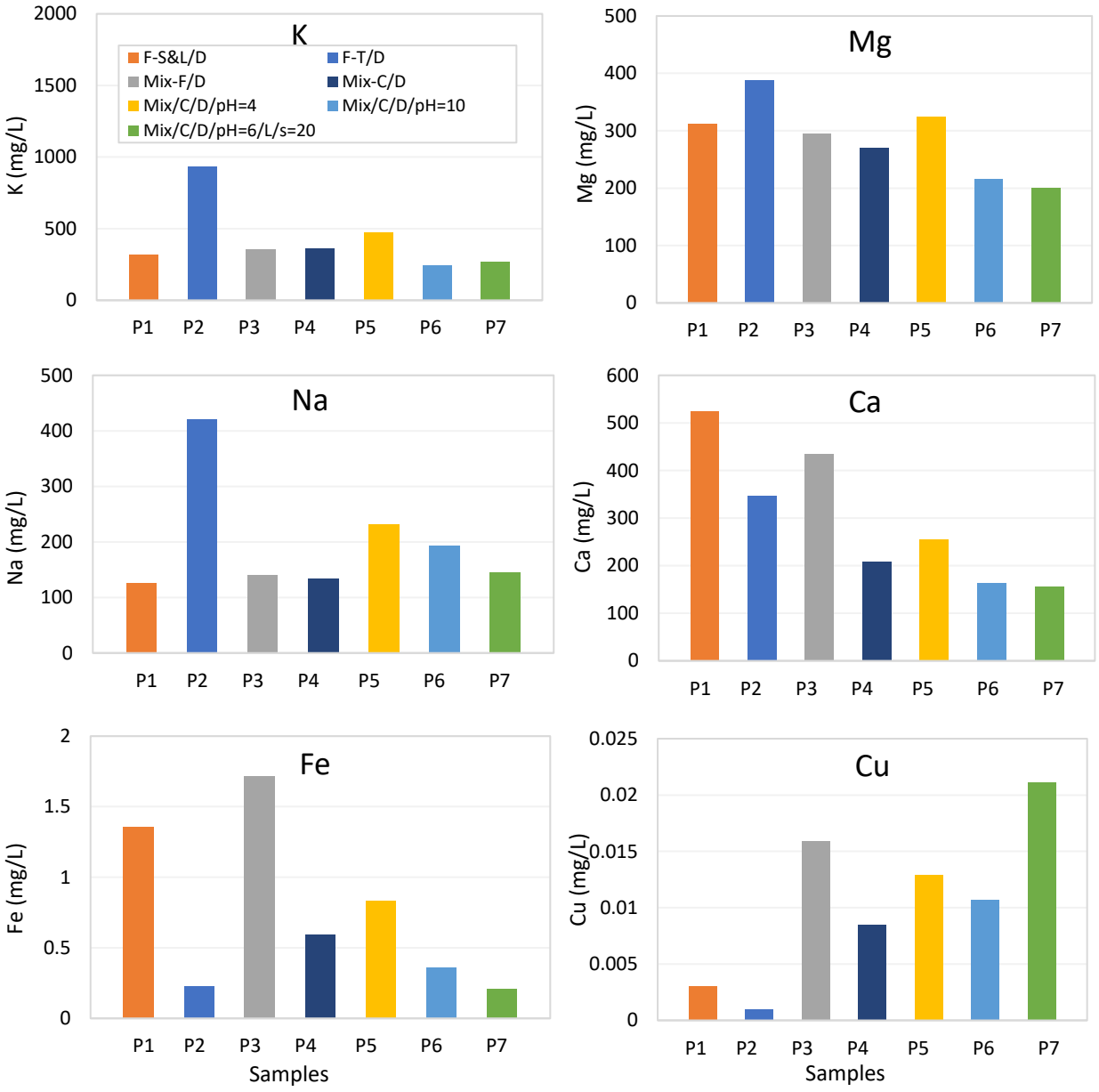


Figure 2: Ions' Release Results at 24 hours after Adding Date-Palm Waste to Distilled Water.

samples reduced the content of TDS, turbidity, and hardness of the reference samples as seen in Figure 3. Perhaps the prewashing and drying process reduced the extraction from the solid waste and

increased its absorbent ability. Samples with fine materials, i.e., P8 and P10, showed higher contents than their relevant samples with coarse materials, i.e. P9 and P11, due to the increase in the surface area of the fine materials, as reported also by Altaher [11].

3.2.2 Ions' Release

Figure 4 shows the results of ions' release at 24 hours after adding date-palm waste to wastewater effluents. In general, the results showed high rates of element extraction into water for samples P8 to P11 in comparison to the reference samples, WII and WIII. Samples P8 and P10 for the fine materials with secondary and tertiary treated wastewater, respectively, showed the highest rate of element release. This is due to the increase in the surface area of the grinded materials and consequently, the increase in the solubility.

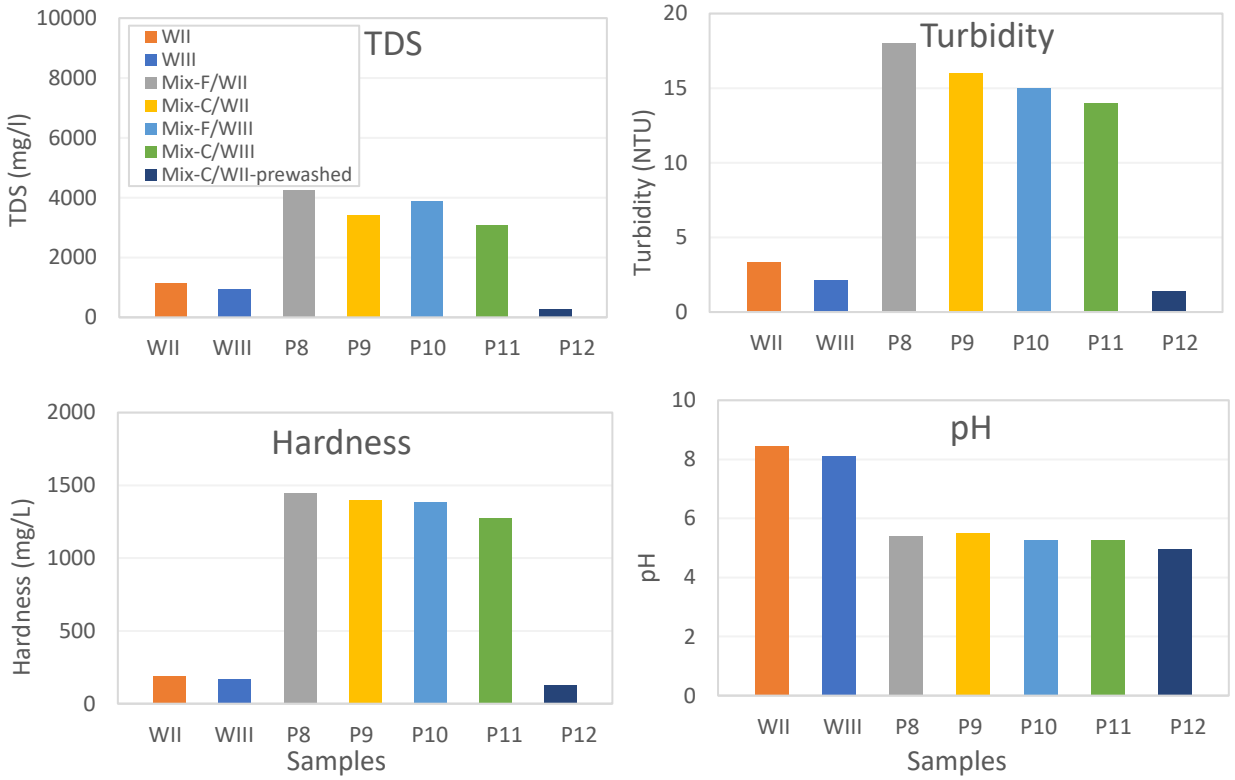


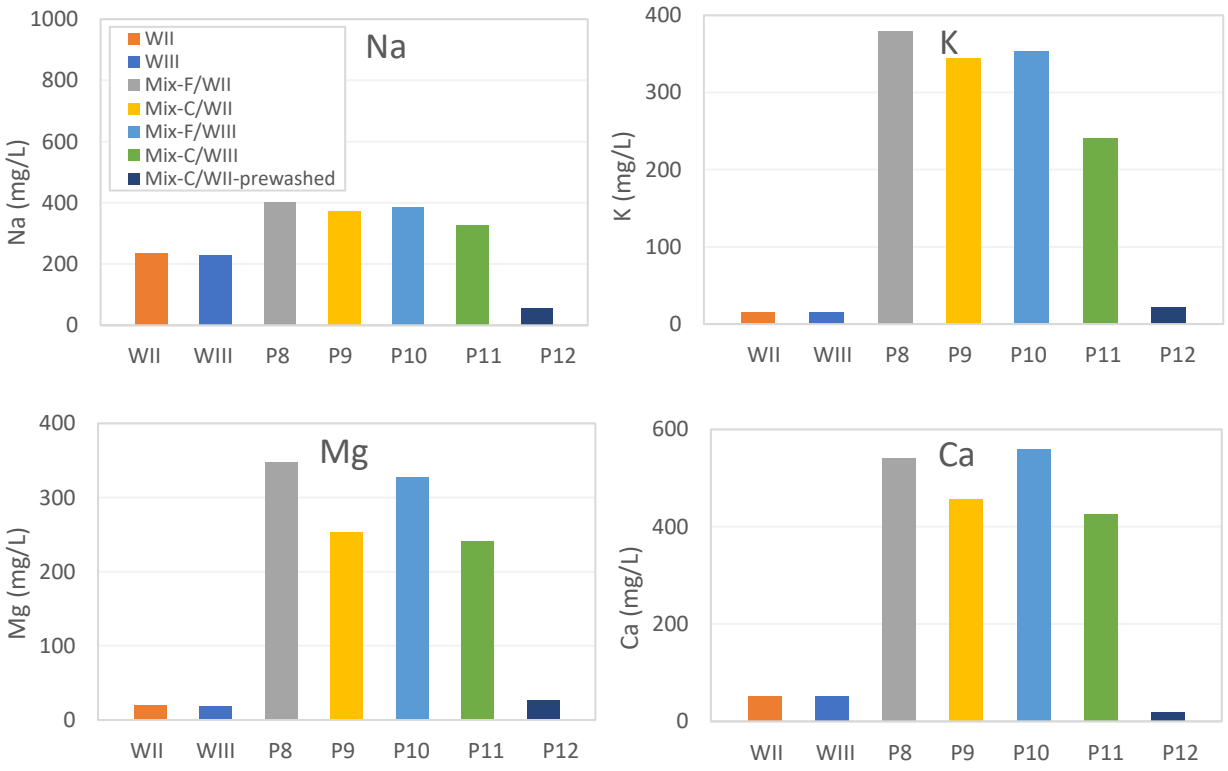
Figure 3: TDS, Hardness, Turbidity, and pH Results at 24 hours after Adding Date-Palm Waste to Wastewater Effluents with Different Parameters.

Sample P9 for the course materials with secondary treated wastewater showed lower levels of the extraction of iron and copper as compared to its relevant samples with the treated wastewater, i.e., P8, P10 and P11. For P12, the prewashed sample, results proved

that adding the waste into water samples reduced the content of most elements in comparison to the reference samples as seen in Figure 4. However, some elements such as K, Mg, and Cu showed a slight and negligible increase more than the original content of wastewater effluents. The result of the prewashed sample indicates the successful possibility of using such type of agro-waste in wastewater treatment after performing a kind of pretreatment for this waste before using it in wastewater treatment application.

3.2.3 BOD and COD

The results of BOD and COD after adding date-palm waste to wastewater effluents are presented in Figure 5. Results of samples P8 to P11 showed a notable increase in BOD and COD values in water samples in comparison to the original content of the reference samples, WII and WIII. A considerable increase was observed in COD. This is perhaps due to the high rate of element extraction into water samples. The case of mixed coarse materials with the prewashing process, i.e., P12, showed notable improvement in BOD and COD values comparing to the previous samples and the original content of



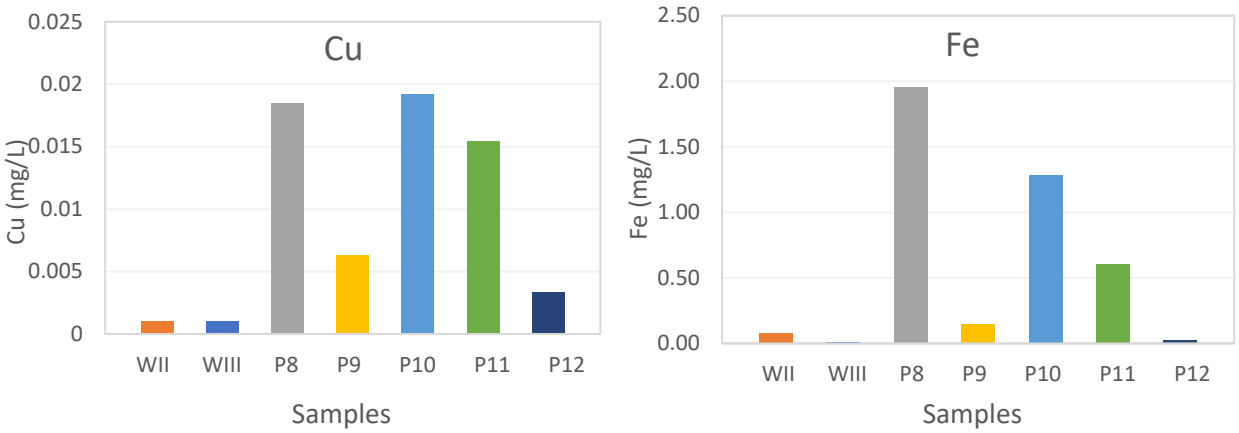


Figure 4: Ions' Release Results at 24 hours after Adding Date-Palm Waste to Wastewater Effluents.

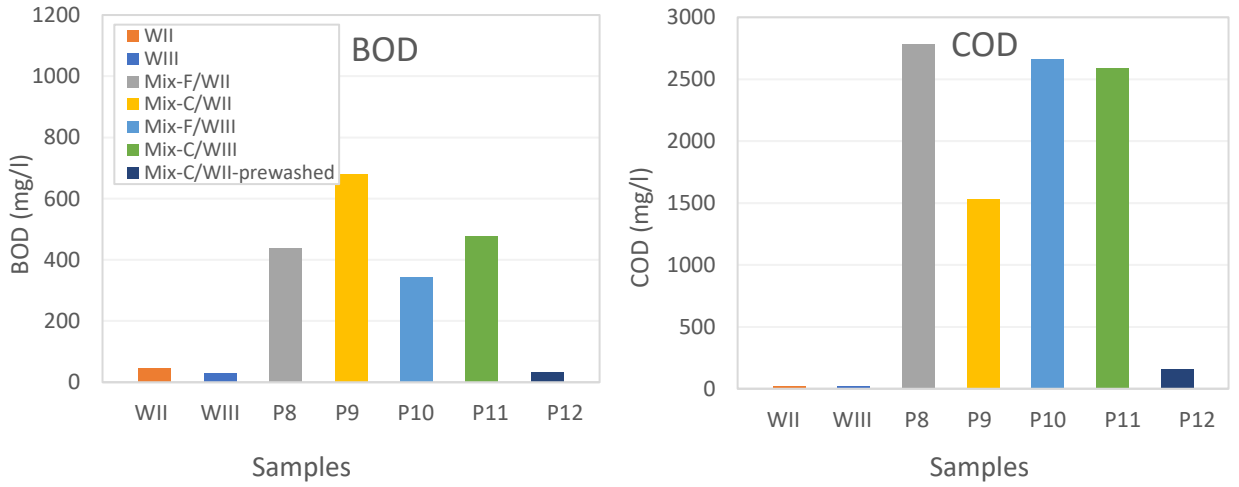


Figure 5: BOD and COD Results at 24 hours after Adding Date-Palm Waste to Wastewater Effluents.

wastewater effluents. BOD decreased by 27% less than original value of WII. This is perhaps of enhancing the empty ion sites and free electrons for improving adsorption process [15], [16]. This result is a promising finding for the treatment process by date-palm waste. Succeeding research is needed to investigate the suitable pretreatment process, which should be applied to this waste before being used as a treatment tool for wastewater effluents.

4. CONCLUSION:

This work studied the possibility of reusing date-palm wastes in the treatment of wastewater effluents relying on an experimental program. The experiments were conducted on a lab scale and various parameters were examined for leaching and absorption processes. The following findings were concluded from the study:

- The results of leaching tests showed, in general, a high rate of extraction of many ions into distillated water at different conditions. The coarse material samples of the waste exhibited less release than those from grinded materials. The conditions of initial pH and liquid to solid ratio have a notable impact on the leaching properties of the waste.
- Results of adding date-palm waste to wastewater exhibited a notable increase of element release into the effluents. BOD and COD values were also raised with the presence of waste in the water samples.
- The prewashing and drying process for the coarse waste before use with wastewater demonstrated a promising ability for this waste to remove many elements from wastewater and reduce BOD values.
- Succeeding research are needed to investigate the suitable pretreatment process, which should be applied to this waste before being used as a treatment tool for wastewater effluents.
- Prewashing plum waste with acid and alkali may enhance the morphological properties, potentially improving removal efficiency. This could be explored in future studies to optimize the recycling process.

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