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REMOVAL OF POLLUTANTS FROM WASTEWATER USING PALM FOUND COMPOSITE ADSORBENT

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Abstract

The increasing apprehension over water contamination calls for the development of novel strategies to ensure efficient wastewater treatment. The objective of this research is to assess the efficacy of a newly developed composite adsorbent, obtained from palm waste, in the context of wastewater treatment for pollutant removal. The present study investigated the use of a sustainable and readily accessible precursor material for the purpose of adsorption, a well-recognized technique employed in the removal of pollutants. The structural and surface characteristics of the synthesized palm-based composite adsorbent were evaluated using different methods. Batch adsorption tests were performed to assess the efficacy of the composite adsorbent in adsorbing various contaminants, such as heavy metals and organic molecules. The investigation evaluated the adsorption efficacy across many parameters, including pH levels, starting concentration of pollutants, and duration of contact. The findings demonstrated that the composite adsorbent derived from palm-based materials had a substantial capability for adsorbing contaminants that are often present in industrial effluent. The kinetic adsorption developed a pseudo-second-order model, indicating that the rate-controlling step is likely chemisorption. Results showed the efficiency of palm waste as a precursor material, offering an economically viable and ecologically sound approach to wastewater treatment. This research highlighted the need to investigate alternate and renewable resources as a means of tackling the issues posed by water contamination. The use of a unique composite adsorbent derived from palm-based materials presented a promising opportunity for the advancement of effective and environmentally friendly approaches in addressing water pollution. This innovation facilitates the incorporation of circular economy ideas within the field of environmental engineering.

Keywords : Wastewater treatment, Composite adsorbent, Pollutant removal, Adsorption, Industrial effluent.

1. Introduction

The introduction of diverse contaminants, such as heavy metals, organic compounds, and dyes [1], into natural aquatic environments has resulted in the degradation of water quality and disruption of ecological equilibrium [2]. Consequently, there is a growing need for novel and efficient approaches to tackle the issues presented by wastewater contamination [3]. The use of adsorption as a method for the elimination of contaminants from wastewater has gained considerable attention in recent years owing to its notable efficacy [4], straightforwardness, and economic viability [5]. Numerous adsorbent materials were investigated for this objective, including activated carbons, zeolites, and naturally occurring adsorbents produced from agricultural and industrial wastes [6]. In recent times, a significant focus on the use of sustainable and renewable resources was developed to obtain efficient adsorbents [7]. Palm materials, which are widely available in several places, provided a distinctive prospect for the fabrication of composite adsorbents that exhibited exceptional adsorption characteristics [8]. The intrinsic porosity and surface chemistry shown by palm-based materials provided good options for applications involving the removal of pollutants [9].

The effectiveness of palm leaves in augmenting the biological treatment of wastewater has not yet been evaluated [10]. The porosity property exhibited by palm leaves has the potential to enhance efficiency. Palm leaves can effectively remove ions and pollutants from wastewater [11]. The findings indicated that the use of palm fronds for filtration had the highest efficacy in removing ions and contaminants from water [12]. Recent study revealed that dehydrated carbon fibers derived from palm fronds had comparable efficacy to activated carbon in the removal of medicines and colors from wastewater [13]. Additionally, these fibers showed remarkable proficiency in eliminating heavy metals, while also possessing the ability to be reused several times [14]. The effectiveness of using palm leaf waste as raw materials to remove organic and mineral pollutants from aqueous solutions is very limited [15]. Adsorbents were used for the purpose of eliminating pollutants or serving as a sustainable energy resource [16]. So, the utilization of palm fronds for wastewater treatment emerges as a compelling choice [17]. In the context of sustainable management, the use of raw solid palm fronds waste may be effectively transformed into an adsorbent material by several methods, including physical, chemical, and thermal modifications [18]. The presence of bio-residues has the potential to give rise to many forms of carbonaceous substances, such as activated carbon, bio-char, and hydrocarbons [19].

The primary objective of this investigation is to ensure the synthesis and characterization of a newly developed composite adsorbent obtained from palm waste. The purpose of this research is to evaluate the effectiveness of this adsorbent in the elimination of diverse contaminants from wastewater [20].

2. Materials and methods

Different contaminated water samples were collected from Iraqi oil refineries (**Fig.1**).

2.1. Filtration Process

The filtration process was executed through the utilization of a custom-designed filter assembly (**Fig.2**). The polluted water traversed through the three interconnected plastic tubes, progressing in series. Notably, every sample was subjected to a triple filtration procedure, with each sample undergoing three consecutive rounds of filtration. Between each filtration cycle, the dry palm fronds, serving as the filter material, were meticulously cleansed. The equipment used for removal of pollutants from wastewater is described in **Fig.3**. This process ensured that the filter material was renewed for the subsequent examination, preventing cross-contamination between samples. Following the filtration process, the resultant filtration consisted of purified water. This purified water, obtained after each filtration cycle, was then subjected to different analyses.

2.2. Analysis of samples before and after filtration

The analysis of results encompassed a comparative evaluation of water samples before and after undergoing the filtration process.

Preparatory steps for analysis

2.2.1. Sample Input: As an initial step, several water samples were introduced into the program's database prior to filtration. The samples were adjusted to pH 7 and maintained at 25°C.

2.2.2. ICP-MS Examination: Prior to the filtration process, water samples were subjected for analysis to determine the relative concentration of chemical elements present in the polluted water. Element composition was assessed using Inductively Coupled Plasma Mass Spectrometry (NexION 5000 ICP-MAS).

2.3. Scanning Electron Microscopy Analysis (SEM)

Morphological analysis and different phases composition was carried out by scanning electron microscopy (SEM-FIB Zeiss Cross Beam 540).

3. Results and Discussion

In this study, we conducted an in-depth analysis of water samples collected from various oil refineries and water sewage refineries in Iraq. Different samples were obtained from these facilities, and their composition was assessed using Inductively Coupled Plasma Mass Spectrometry. The detailed results of this analysis are presented for three samples in **Figs 4, 5 and 6**. To establish a baseline for comparison, a set of data points was initially extracted from the raw samples. These samples were then subjected to the **NITTO PROGRAM**, which provided ideal reference values. The aim was to use these ideal reference values as a benchmark against which to evaluate the effectiveness of the filtration process. A photo of the three samples before and after filtering is presented in **Fig.7**. The difference is clear between treated and untreated samples.

3.1. Filtration results

To assess the filtration device's efficacy in purifying contaminated water, a comparative study was undertaken. The results of three samples were juxtaposed before and after the filtration process. This comparative analysis aimed to determine the filtration device's ability to remove contaminants from the water samples.

ICP-MS analysis presented the elemental concentrations of a set of 3 samples across three distinct stages. The initial state as polluted water, the intermediate state following treatment through the Nitto program, and the final state as post-filtration. From this data, several observations and conclusions can be drawn:

3.1.1. Element Removal: The Nitto program and subsequent filtering demonstrated significant effectiveness in decreasing the content of diverse components in the water samples. It is worth mentioning that there are considerable decreases reported in the concentrations of many elements, including calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), barium (Ba), strontium (Sr), bicarbonate (HCO_3), fluoride (F), nitrate (NO_3), phosphate (PO_4), and silicon dioxide (SiO_2). Variable Impact: Different elements respond differently to the treatment processes. Some elements experience extensive reduction (e.g., Ba, Sr, F), while others show moderate reduction (e.g., Ca, Mg) or minimal change (e.g., NH_4, pH).

3.1.2. Challenging Elements: Elements such as NH_4, B, and pH showed little variations after the implementation of the Nitto program and filtration, indicating their resilience against these procedures. Ionic Compounds: Ionic compounds such as Cl and SO_4 experience moderate to significant reductions through the Nitto program and subsequent filtration, indicating effective removal of these constituents.

3.1.3. Total Dissolved Solids (TDS): The Total Dissolved Solids (TDS) value exhibited a significant decline after the implementation of the Nitto program and filtration, so underscoring the efficacy of these procedures in diminishing the total concentration of dissolved substances' adjustment. The pH values demonstrated changes after the treatment stages. Although the pH values did not achieve the exact optimal value of 7.2 after filtration, they did approach a more neutral range, signifying an attempt at pH adjustment.

3.1.4. Complex Elements such as NO_3 showed significant decreases after the implementation of the Nitto program. However, these elements suffer a comparatively smaller drop throughout the filtering process, suggesting the presence of a multifaceted mechanism for their removal. For effectiveness assessment, the results substantiated the overall effectiveness of the Nitto program and filtration process in improving water quality by reducing the concentration of various pollutants and impurities.

3.2. Nitto program results

A computational tool, specifically the NITTO HYDRANAUTICS program, was employed to undertake predictive analysis by inputting numerical data and subjecting it to analysis. The data input encompassed samples procured prior to the filtration procedure. Subsequently, a filter variant was selected from within the program, namely the (ESPA2 MAX 12000), which exhibits computational analogs to the filtration mechanisms observable in palm fronds. Upon commencement of program utilization, it is requisite to establish the pH value at 7, a benchmark denoting the optimal point for water chemical equilibrium. Furthermore, a temperature of 25°C, representative of ambient conditions, was set. Validation was executed through utilization of the ICP-MAS instrumentation, positioned in proximity to each constituent element within the program's framework. From this dataset, numerous insights can be derived regarding the alterations in ion concentrations at distinct stages of the treatment process, thereby contributing to a comprehensive comprehension of the efficacy and impact of the undertaken treatment procedures on the water sample.

In essence, the presented data underscores the diverse responses of different elements to the treatment processes, highlighting the complexity of water purification mechanisms. The outcomes serve to guide further research into optimizing treatment protocols for specific elements and refining the Nitto program-filtration combination to achieve targeted water quality improvements.

3.3. SEM study

The morphology of the treated samples was analyzed by SEM. Micrographs of the three samples are presented in **Fig.8**. The three samples are different in terms of morphology of the remained particles and their size. It seems that the sample 3 is clearer than the samples 1 and 2, because of the absence of high size aggregates. Besides, sample 1 looks darker than the others (**Fig.7**). This result could be explained by a possible aggregation phenomenon between the fine particles that resist in the filtrate, as confirmed in recent works [21]

By combining ICP-MAS and SEM techniques, this study presented a comprehensive understanding of the initial composition of water samples, the potential for filtration, and the subsequent improvements achieved. The detailed data and insights obtained from this study contributed to advancing the knowledge of wastewater treatment in the context of Iraqi refineries.

Conclusion

The current research investigated a new method involving the use of a composite adsorbent derived from palm for removing contaminants from wastewater. The effectiveness and potential of this sustainable adsorption material were explored via a thorough series of tests and studies. The palm-based composite adsorbent demonstrated exceptional efficacy in removing pollutants, indicating its promise as a highly efficient adsorption material. The increased adsorption performance of the adsorbent may be attributed to its intrinsic porosity and the alteration of its surface chemistry. The comparative investigation revealed the distinctive benefits of the palm-based composite adsorbent in comparison to other commonly used adsorbents. SEM study showed good homogeneity and high uniformity of the treated samples despite the presence of particles or aggregates resulted from coagulation phenomenon. In summary, this research highlighted the capacity of palm-based composite adsorbents as a novel and environmentally friendly approach for the elimination of contaminants from wastewater.

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Figure captions

Fig. 1. Sample collection from Iraqi oil refineries.
Fig.2. Filtration process of different samples.
Fig.3. Removal of pollutants from wastewater using palm found composite adsorbent equipment.
Fig.4. ICP-MAS analyses of the sample 1 before and after treatment.
Fig.5. ICP-MAS analyses of the sample 2 before and after treatment.
Fig.6. ICP-MAS analyses of the sample 3 before and after treatment.
Fig.7. Photo of samples before and after filtering.
Fig 8. SEM analyses of sample 1.
Fig 9. SEM analyses of sample 2.
Fig 10. SEM analyses of sample 3.

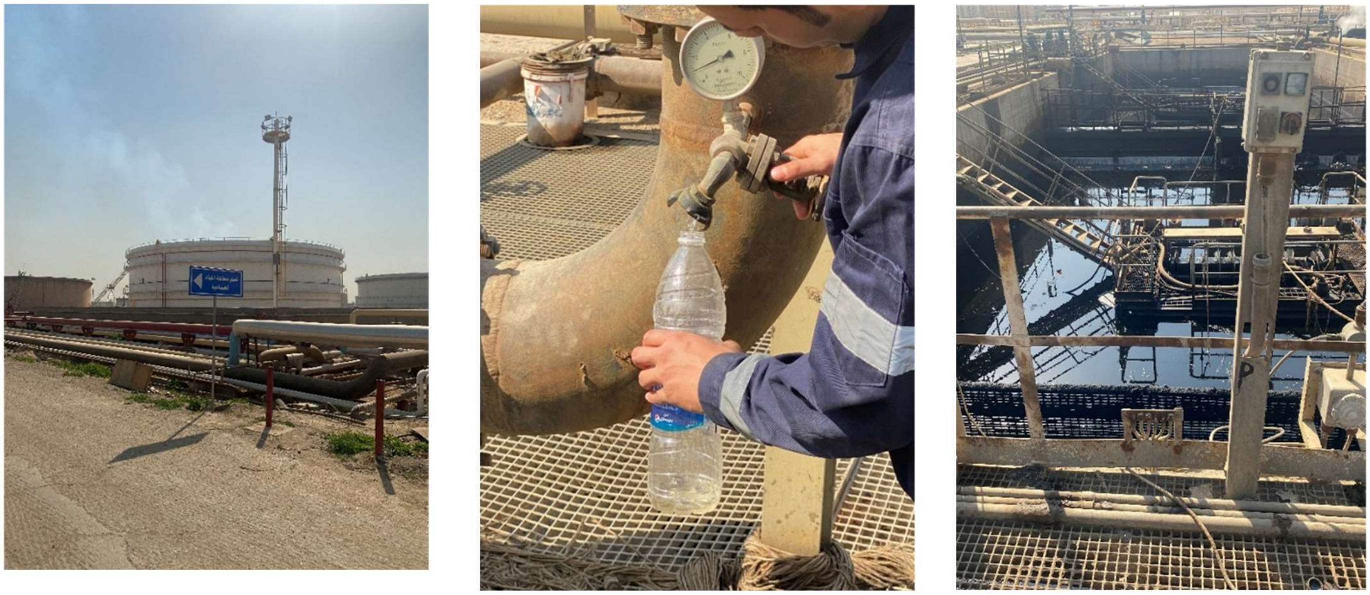

Fig.1

Fig.2

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Figure 3

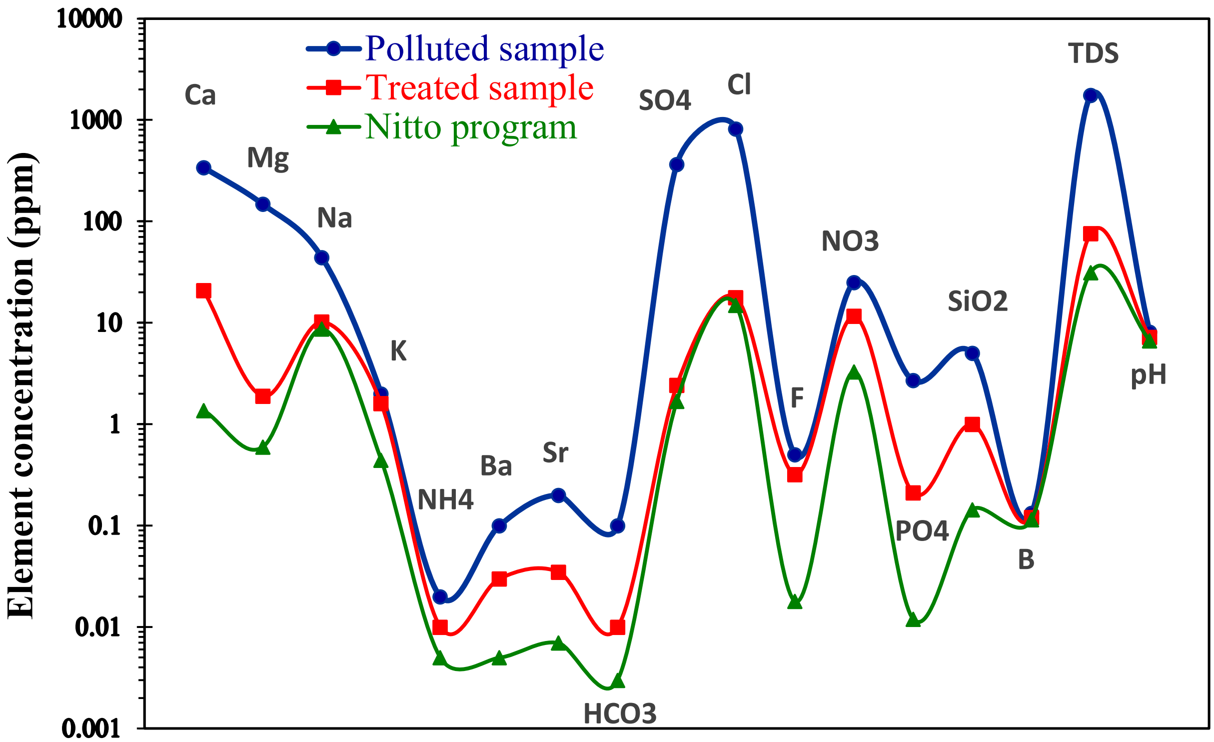
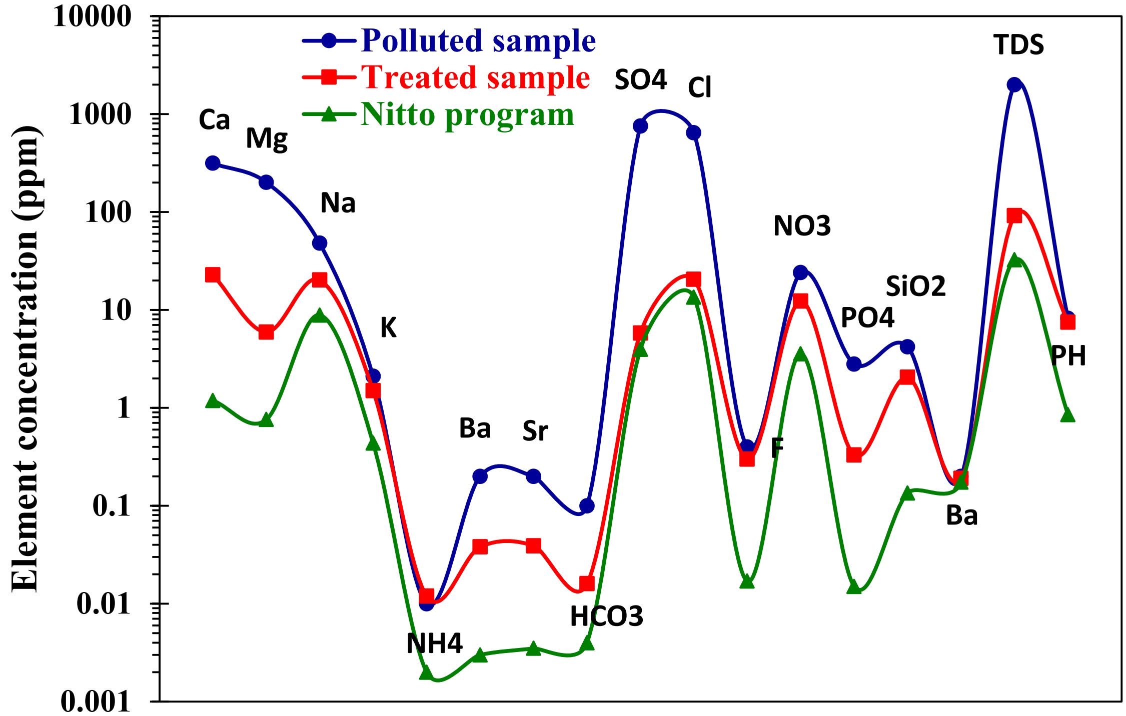


Fig.4


Polluted sample
Treated sample
Nitto program
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1000
100
10
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0.1
0.01
0.001
Ca
Mg
Na
K
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Ba
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HCO3
SO4
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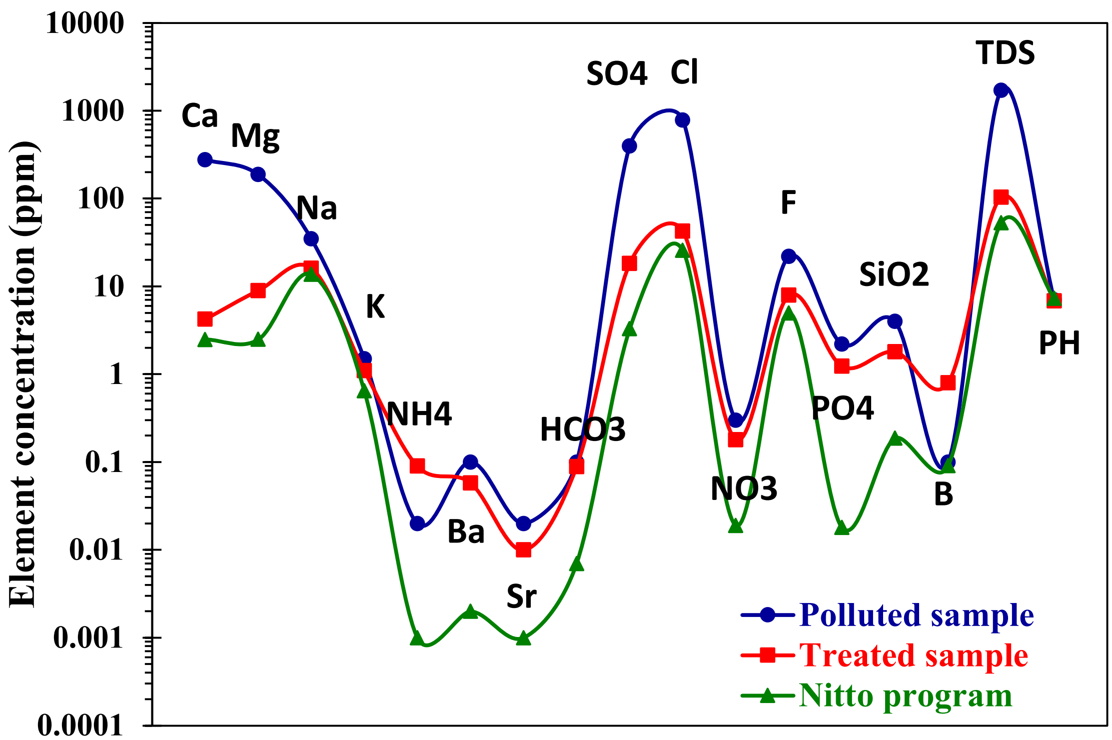
F
NO3
PO4
SiO2
Ba
TDS
PH

Fig.5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Cl
NO3
F
PO4
SiO2
B
TDS
PH
Polluted sample
Treated sample
Nitto program

Fig.6

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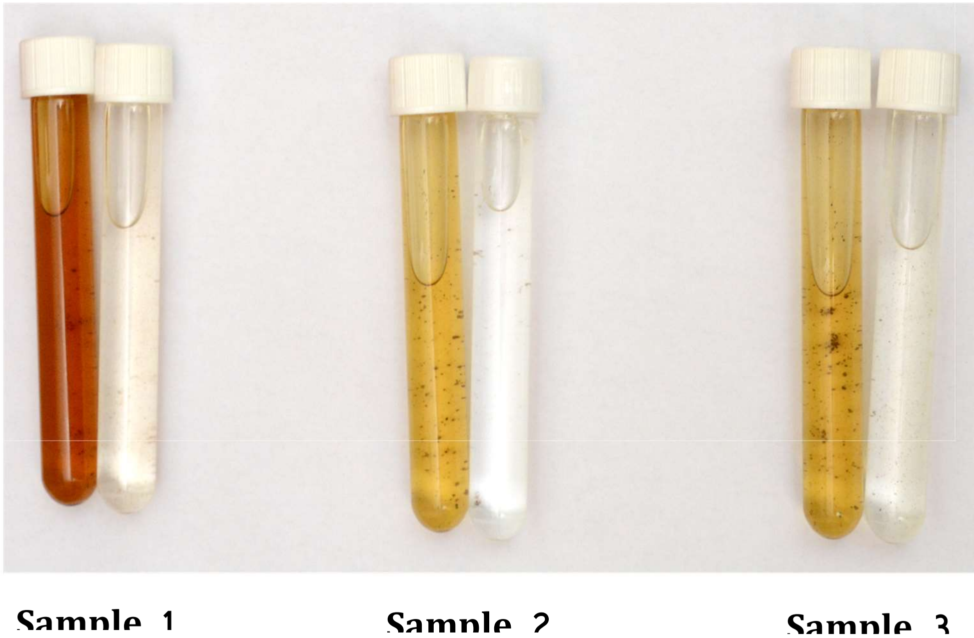
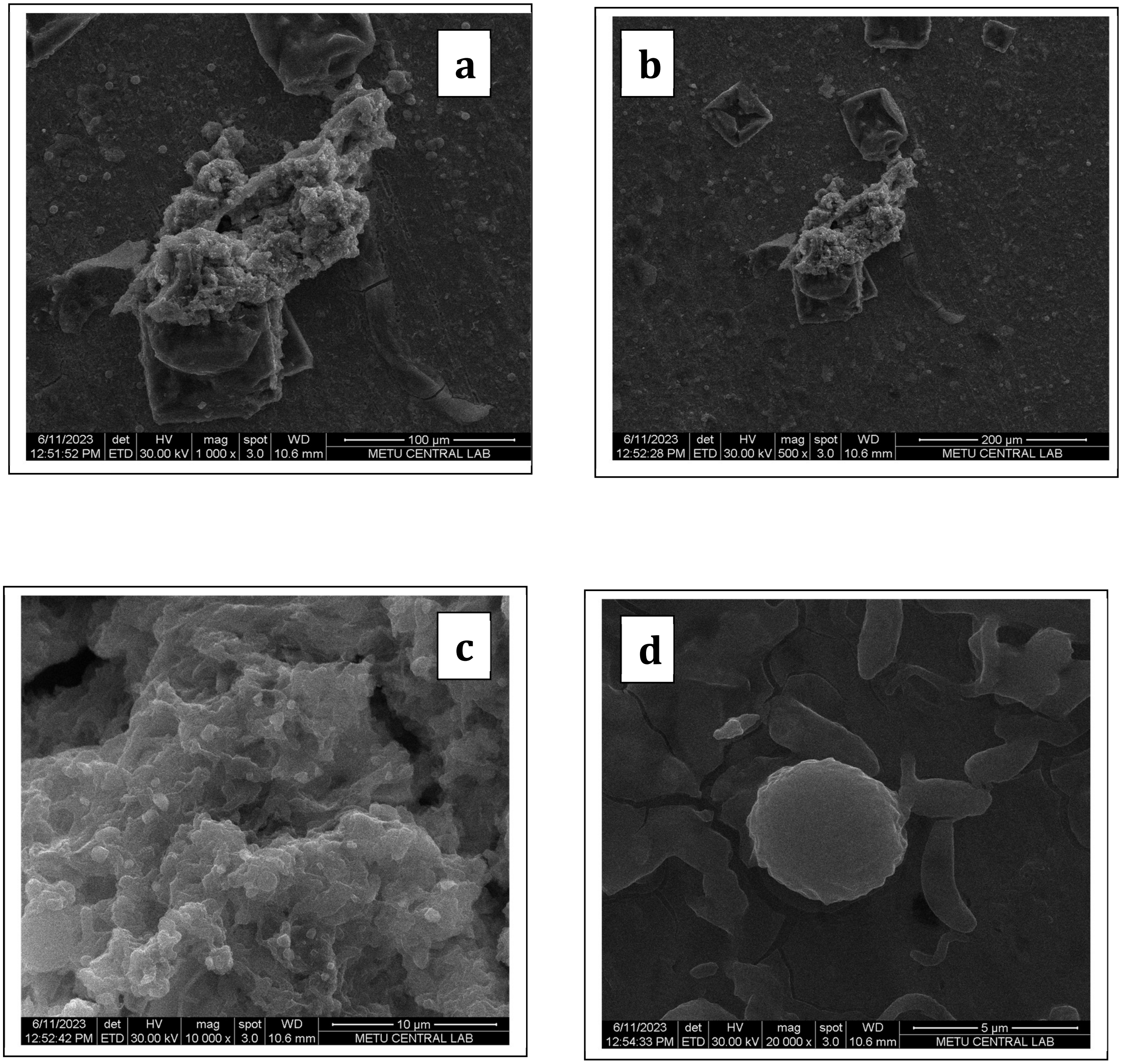


Fig. 7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c
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d
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Fig. 8

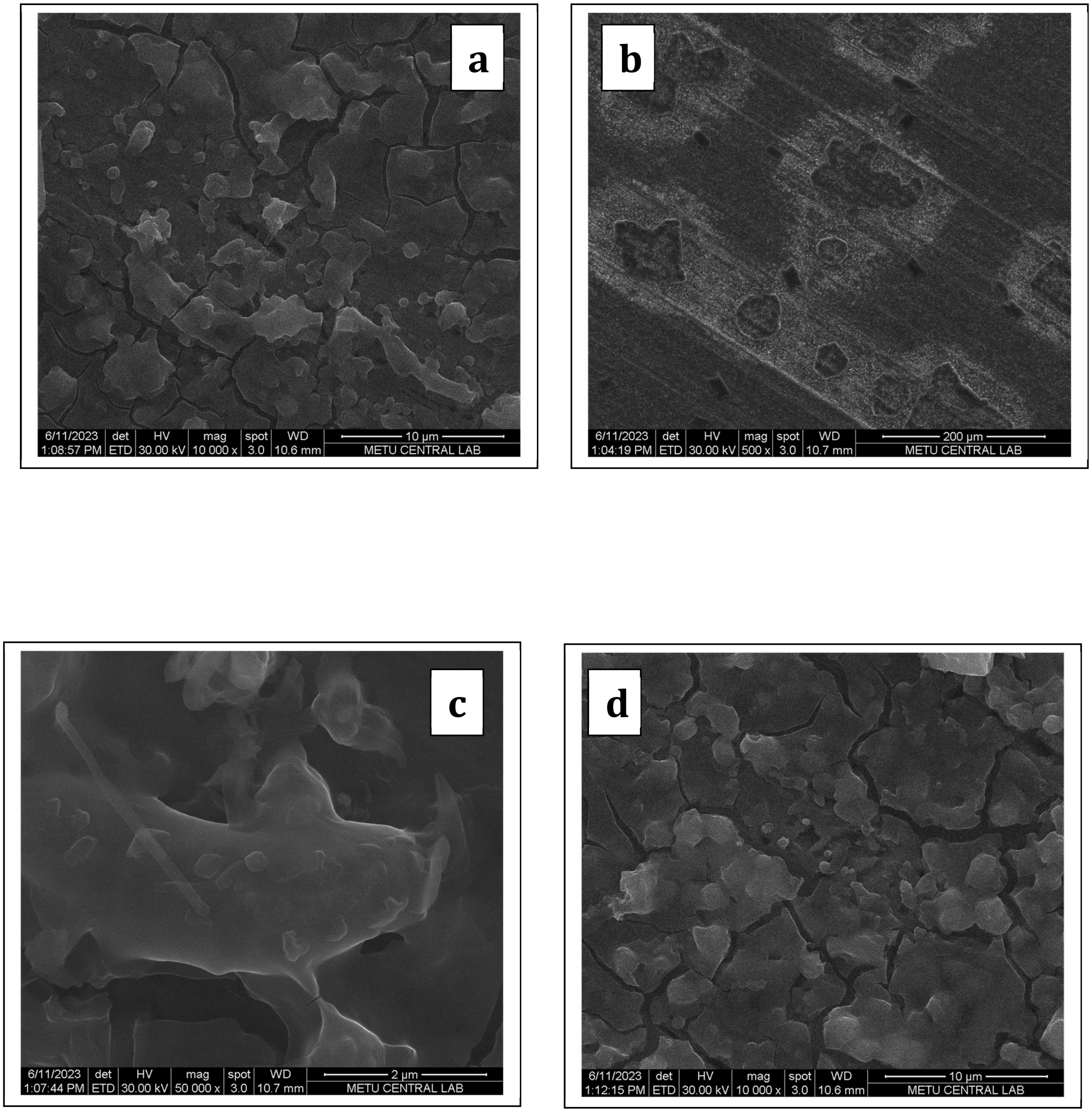
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Fig. 9

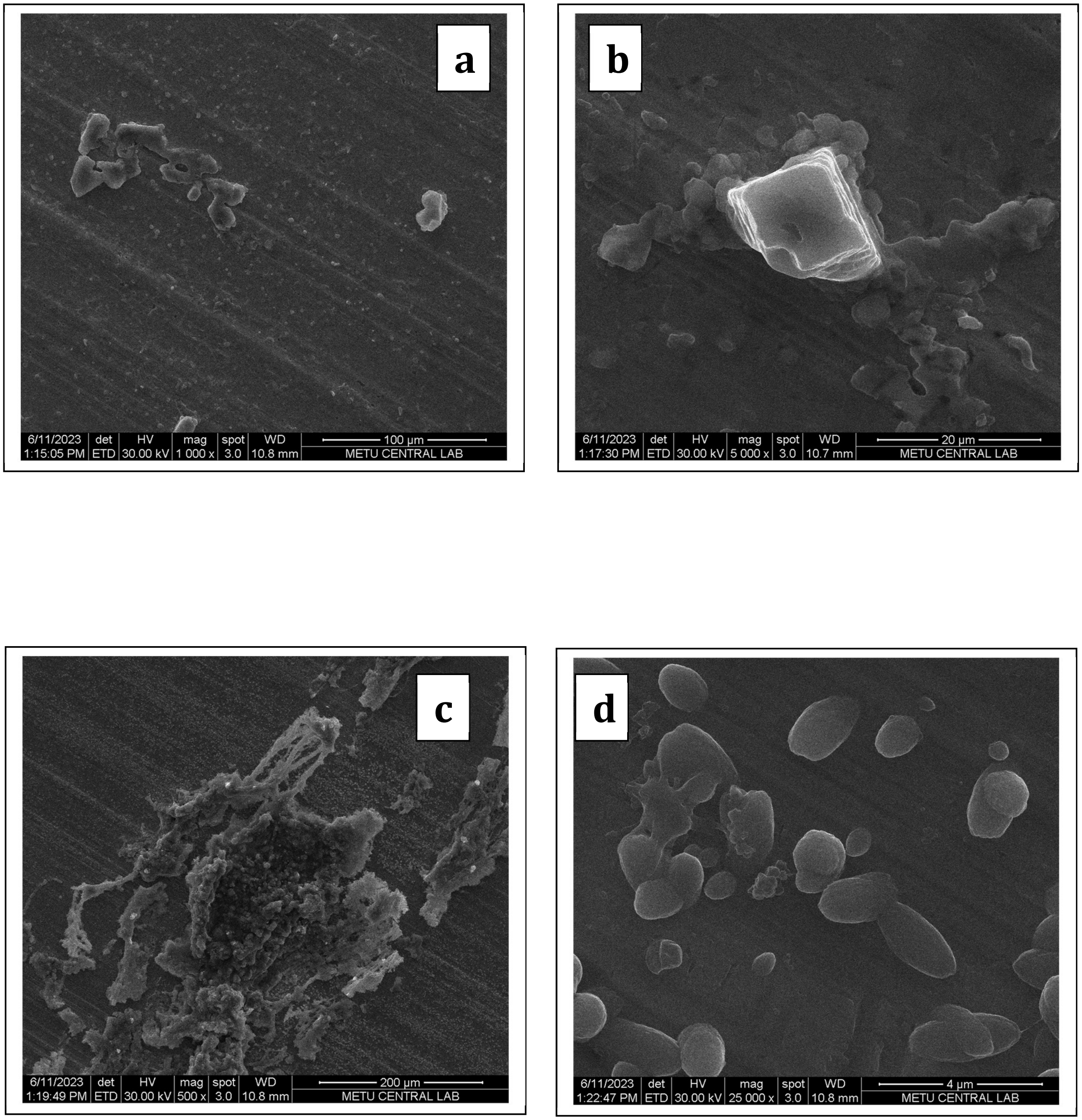
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Fig. 10