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S poštovanjem,

Dr Dejan Kojić, vanredni profesor
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EDITORS' INTRODUCTION

Dear fellow authors, distinguished readers,

In front of you is the second issue of the scientific journal of social and technological development - STED Journal in 2024, published by the University of Business Engineering and Management. The first second in 2024 includes 8 papers and 6 of them are original scientific papers. Published papers have got a positive review by two independent reviewers. Reviews are anonymous and reviewers do not know the author's identity. Reviewers have also suggested the sorting of papers into scientific and expert categories. Reviewers have given their consent for publishing of paper based on their assessment of originality, novelty, used methodology and literature of paper.

Each paper is assigned COBISS, UDC and DOI number by the National and University Library of the Republic of Srpska. The journal has its analytically revised articles which are published in the current national bibliography, and it is included in the central electronic catalogue. All members of the editorial board have scientific or educational titles from the narrow scientific fields covered by the journal. The journal is included in the ERIH+, DOAJ, CEEOL, INDEX COPERNICUS, GOOGLE SCHOLAR and OPAC citation databases.

On the last pages of the journal, there is also the bibliography of papers published in the first issue in 2024.

We thank the reviewers of papers whose professionalism and critical approach have greatly contributed to the quality of published papers.

With best wishes,

Dr Dejan Kojić, associate professor
Editor-in-Chief

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ADVANCING PLANT METABOLISM ANALYSIS: A REAL – TIME OPTICAL APPROACH, INSIGHTS FROM *VRIESEA CARINATA WAWRA*

Sara V. Ristić[1], Miloš S. Mošić[1], Marija M. Petković Benazzouz[1], Stefan Lekić[2], Katarina M. Miletić[1]

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Ristić, S.V., Mošić, M.S., Petković Benazzouz, M.M., Lekić, S., & Katarina, M.M. (2024). Advancing plant metabolism analysis: a real-time optical approach, insights from Variesea carinata Wawra. *STED Journal*, *6*(2), 1-9.

ABSTRACT

Optical detection of plant stress in real-time is crucial as it enables timely interventions to mitigate potential damage. This study presents a detailed evaluation of a system that detects changes in plant metabolism in real-time by distributing optical signals across the leaf. The methodology facilitates continuous monitoring of changes in the optical properties of plant leaves through measurements of optical transmission coefficients using a 665 nm LED light signal, thereby recording the circadian rhythm over time. Given that the photosynthetic processes within the leaves are closely linked to the plant's overall health, this system can detect stress caused by various factors and identify metabolic changes by analysing the circadian rhythm patterns of the observed plants.

For inducing metabolic changes, the plant *Vriesea carinata Wawra*, a verified representative of dual metabolism, was subjected to high light intensity stress. To validate the method, the collected results were compared with data obtained through chemical methods to establish a correlation between the traditional, destructive method and the non-destructive, optical method.

The findings successfully identify circadian rhythms as parameters for recognizing changes in plant metabolism, demonstrating the significance of the proposed method in researching plant physiology through the optical identification of biological processes.

Keywords: Plant metabolism, Circadian rhythm, Non-destructive method, Real-time optical approach, Stress detection.

INTRODUCTION

Modern plant cultivation practices require continuous monitoring of various parameters affecting plant health. Early stress detection is crucial for predicting the success of growing particular plant species (Shah, Houborg, & McCabe, 2017). Identifying plant stress is essential for improving agricultural practices and preserving plant resources. According to the United Nations, climate change leads to significant soil degradation and air composition changes, indirectly impacting food quality (Rumbaitis, & Guilanpour, 2023). Effective monitoring of plant physiological status can significantly reduce agricultural losses, enhance yields, and minimize the use of chemical agents.

Traditional approaches to monitoring plant health often rely on time-consuming, subjective, and destructive methods. These methods involve physicochemical analyses of plant tissues, requiring detailed sample preparation (Kvet, Ondok, Necas, & Jarvis, 1971). It is well established that a plant's overall health correlates with the intensity of all photosynthetic processes in its leaves (Knapp, & Carter, 1998). To achieve continuous monitoring of vital plant processes, non-invasive methods are increasingly employed, providing insights into plant health and metabolic changes by measuring the spectral characteristics of leaves throughout the growth and life cycle. These methods are based on specific wavelengths of light used to measure optical properties of plant leaves, such as transmission and reflection (Gitelson, Gritz & Merzlyak, 2003; Combes et al., 2007; Liu, & van Iersel, 2021).

A novel method in this field has been developed at the Faculty of Physics, University of Belgrade, within the Department of Applied Physics and Metrology. This method enables continuous real-time monitoring of the physiological and health status of plants and their metabolic processes (Kasalica et al., 2021). This innovative system uses specific spectral responses of plant leaves to appropriate stimuli necessary to define optimal conditions for the development and growth of certain plant species. By tracking circadian rhythms, this method allows early detection and precise identification of stress states caused by factors such as changes in light intensity, nutrient deficiencies, herbicide use, or pathogen presence (Miletic et al., 2022; Miletic, Mošic, Ristic, & Petkovic-Benazzouz, 2023; Veljovic Jovanovic et al., 2023).

One of the critical aspects of monitoring plant metabolism is detecting the transition between C3 and CAM metabolism. C3 plants use the Calvin-Benson cycle for carbon dioxide fixation, while CAM plants assimilate carbon dioxide at night to reduce water loss during the day. The transition between these two types of metabolism is a significant indicator of plant adaptation to stress conditions, such as intense light exposure (Maxwell et al., 1995; Winter & Holtum, 2021). Understanding and detecting this transition is crucial for researching plant adaptive mechanisms and their responses to environmental changes. Through precise analysis of the spectral responses of leaves to various external factors, this method offers a more accurate insight into plant adaptive mechanisms, enabling the development of effective strategies to improve plant health and productivity.

The aim of this study is to investigate the correlation between the circadian rhythm function obtained using the non-invasive optical method and the concentrations of malic and citric acids after exposing plants to light stress.

MATERIAL AND METHODS OF WORK

Plant Material

A group of five *Vriesea carinata Wawra* plantlets, all genetically identical clones, was cultivated in a controlled environment within a growth chamber (Figure 1). The conditions were meticulously regulated, maintaining a constant temperature of 22/23°C (day/night), a 12/12-hour photoperiod, relative humidity around 70%, and a light intensity of approximately 140 µmol/s/m².

Figure 1. *Vriesea carinata Wawra* seedlings used in the experiment

Stress Induction by Light Intensity Variation

To induce stress through changes in light intensity (Group A), an initial set of five *Vriesea carinata Wawra* plantlets was exposed to light at an intensity of PPFD = (140±30) µmol/s/m². Over the subsequent three days, the light intensity was increased to PPFD = (850±60) µmol/s/m². This adjustment was implemented to simulate stress caused by a sudden change in light intensity, thereby triggering the transition of the plant from C3 to CAM metabolism.

Chemical Method for Determining Malic Acid Concentration

For the chemical determination of malic acid concentration, leaf samples were collected at night before stress and after stress. A single leaf from each plant was immediately immersed in liquid nitrogen, then ground into a fine powder. Two grams of each sample were mixed with 10 ml of 80% (v/v) aqueous ethanol solution. After homogenizing the mixture for one minute, the samples were subjected to ultrasonic treatment for 30 minutes. The mixture was then centrifuged at 3,000 rpm for 5 minutes. Post-centrifugation, 100 µl of the supernatant was diluted with 900 µl of the mobile phase (10% solution A and 90% solution B), and filtered through a 0.45 µm Nylon filter. Finally, 20 µl of the filtrate was analyzed using liquid chromatography (LC) (Fernández-Fernández, et al., 2010).

NOM for Displaying Circadian Rhythm

In this experiment, the Non-invasive Optical Method (NOM) described in detail in Kasalica et al. (2021) was utilized. This method enabled the monitoring of the circadian rhythm of light transmission through the leaves of *Vriesea carinata Wawra*.

The system consists of 20 identical segments, each corresponding to a measurement point where a plant leaf sample is placed. For the growth chamber housing the *Vriesea carinata Wawra* plants, 10 measurement points were designated, with two measurement points per plant, resulting in a total of 10 measurement points for the five plants. This setup ensured the acquisition of statistically reliable data on the circadian rhythm.

Each segment of the system includes a leaf holder made of transparent plexiglass, allowing for movement in six degrees of freedom to accommodate the natural movement of the leaf (Figure 2).

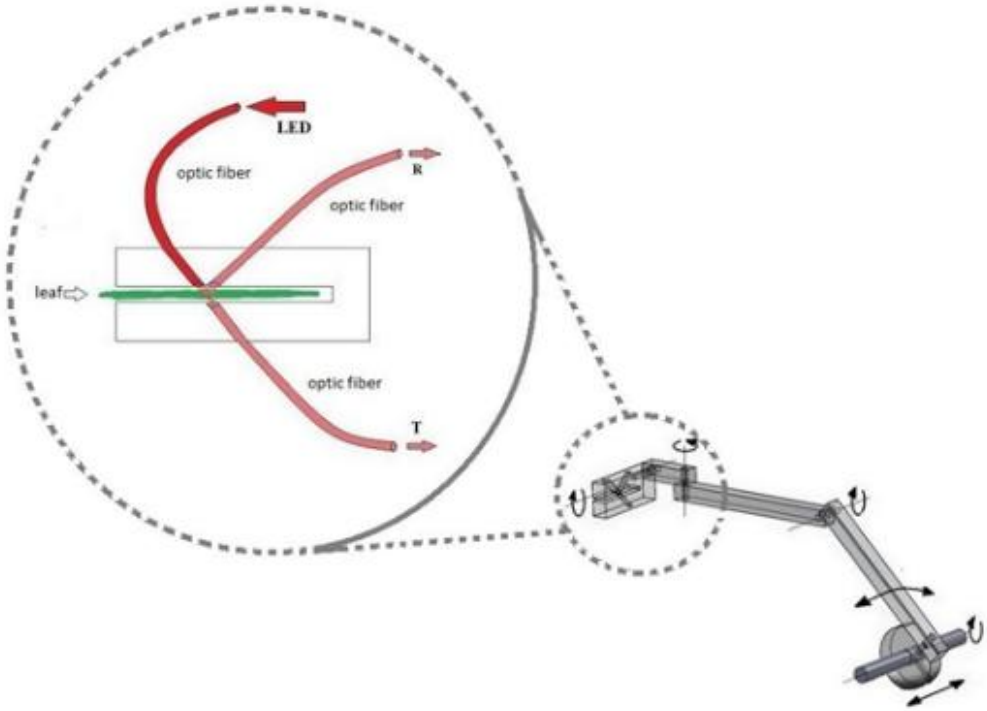

Figure 2. Single measurement channel (Kasalica et al., 2021)

The holder has three slots for optical fibers, positioned at a 45-degree angle relative to the plane of the leaf. These optical fibers are used to illuminate the leaf with an LED (corresponding to the wavelength of maximum chlorophyll-a absorption at 665 nm), collect reflected light, and collect transmitted light, respectively. One end of the fiber optic cable is placed near the leaf, while the other end transmits the signal to an appropriate photodiode. Above the photodiode surface, a filter is placed to allow only light of a specific wavelength (corresponding to the LED wavelength of 665 nm) to pass through. A focusing lens ensures that the light beam is concentrated on a small area to prevent light scattering.

The photodiodes send signals to a measurement device (I/O card), and using appropriate electronics, a graph of the transmission coefficient over time is plotted, depicting the circadian rhythm (Kasalica et al., 2021).

Statistical Analysis

To determine the relationship between optical measurements (transmittance) and biochemical parameters (total acidity), the Pearson correlation coefficient was used. This coefficient quantifies the linear dependence between two variables, where values range from -1 to 1, indicating the strength and direction of the relationship.

In this study, transmittance was measured as part of the optical analysis before and after light stress, while total acidity was assessed through chemical analysis of the plant leaves. The correlation coefficient was used to determine whether a significant linear relationship existed between these changes in the plant, considering the relationship between transmittance at night and during the day, before and after the transition from C3 to CAM metabolism.

RESULTS AND DISCUSSION

Results Obtained by Non-invasive Optical Method

One of the results illustrating the circadian rhythm obtained using the non-invasive optical method is shown in Figure 3. This figure demonstrates the temporal variation in light transmission through the leaves of *Vriesea carinata Wawra*, highlighting the effectiveness of the method in monitoring circadian rhythms in real-time.

All five samples in both groups exhibit the same trend in the circadian rhythm function, with only differences in the percentage of transmission, which depends on the position and thickness of the leaf relative to the fiber optic cable and leaf holder. Therefore, only one graph per group is presented.

Analysis of the results obtained using the non-invasive optical method reveals significant differences in the circadian rhythm function of plants due to changes in light conditions, covering a period of three days before and four days after the increase in light intensity. Under normal conditions, a consistent circadian rhythm was recorded, characterized by a decrease in transmission during the day (Figure 3), indicating increased absorption.

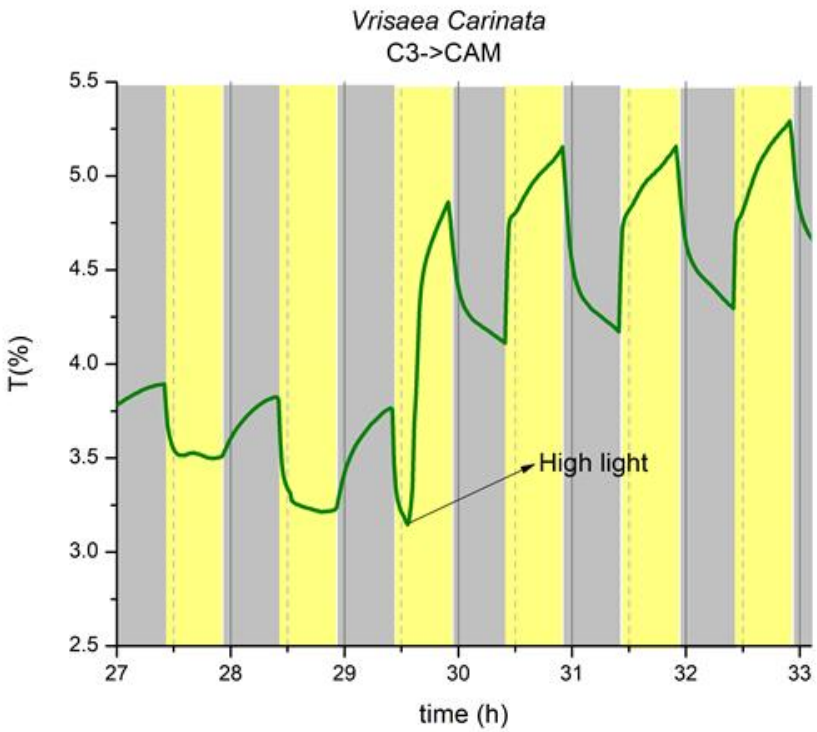

Figure 3. Circadian rhythm of plants (change in light intensity)

After the change in light intensity, a complete inversion in the circadian rhythm of light transmission was observed, with transmission being lowest during the night (gray area in Figure 3), suggesting a metabolic shift as the plants minimize water loss through stomata during daytime heat.

Interestingly, smaller peaks were recorded at times when the lights were turned on or off. These changes effectively demonstrate how plants respond to alterations in their light environment, providing clear evidence of the spectral response of plants to modified lighting conditions.

Results Obtained by Chemical Method

The results obtained by the chemical method are presented in Figures 4a and 4b. These figures illustrate the measured concentrations of malic acid in the leaf samples under different conditions.

The obtained results show diurnal fluctuations in the concentrations of these acids, which align with the known patterns for plants utilizing CAM and C3 metabolism. For CAM plants, the concentration of malic acid is significantly higher at night when CO_2 is fixed in the form of organic acids while the stomata are open, and lower during the day when these acids are broken down. This is clearly visible in our results, where CAM plants exhibit high nighttime values of malic and citric acids that decrease during the day (Haag-Kerwer, Franco, & Luttge, 1992). Conversely, C3 plants do not show significant fluctuations in malic acid concentration. Our data confirm this pattern, as the concentration of malic acid in C3 plants remains relatively stable throughout the day and night (Haag-Kerwer, Franco, & Luttge, 1992).

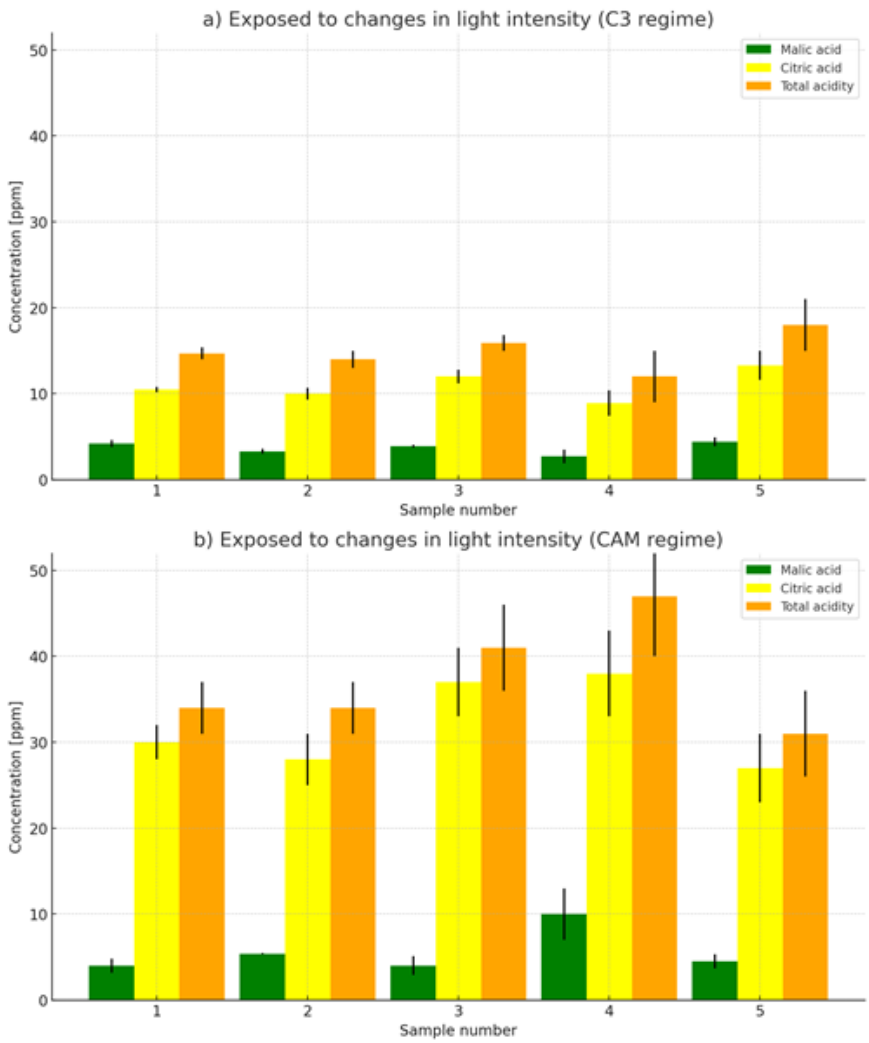

Figure 4. Concentration of malic and citric acid in *Vriesea carinata Wawra* samples a) C3 regime b) CAM regime

Statistical Analysis of the Correlation Between Optical and Chemical Data

To provide further insight into the relationship between the changes observed through the non-invasive optical method and the biochemical analysis, we calculated the Pearson correlation coefficient between the ratio of transmittance during the night and day (max/min ratio) and the total acidity values before and after increasing light intensity.

The calculated Pearson correlation coefficient was $r = -0.956$, indicating a strong negative linear correlation between the changes in light transmittance and the total acidity in the leaves of *Vriesea carinata Wawra*. This suggests that as transmittance decreases during the day (indicating increased absorption and CAM activity), the total acidity significantly increases, which is consistent with the expected physiological response during CAM metabolism.

These results emphasize the strong negative correlation, highlighting the reliability of the non-invasive optical method in detecting metabolic changes and confirming its agreement with chemical analysis. The estimated uncertainties were considered for both transmittance ratios and acidity measurements, ensuring a comprehensive understanding of variability in the data.

Our hypothesis about plant metabolism based on the non-invasive optical method aligns with the results obtained from chemical analyses. The study by Herppich, von Willert, & Herppich (1995) demonstrates similar fluctuations in the concentration of organic acids in plants transitioning from C3 to CAM metabolism under stressful conditions, such as drought or high light intensity (Herppich, von Willert, & Herppich, 1995). This consistency supports the reliability of our findings and underscores the effectiveness of the non-invasive optical method in monitoring metabolic changes in plants.

Furthermore, it is important to note that studies involving CAM physiology, particularly those focusing on metabolic changes under varying light intensities, often use a relatively small sample size due to the complexity and controlled nature of the experiments (Haag-Kerwer, Franco, & Luttge, 1992). Similar approaches have been documented in the literature, where small sample sizes are used to achieve in-depth physiological insights with precision under carefully regulated conditions. This highlights that our study design, despite the limited number of samples, is in line with the best practices for research of this type and provides robust evidence of the observed metabolic shifts.

CONCLUSIONS

This study provides the first evidence that plant metabolism can be determined non-destructively through the application of the Non-invasive Optical Method (NOM) on *Vriesea carinata Wawra*. The method was validated using chemical analysis of leaf acidity, demonstrating a strong correlation ($r = -0.956$) between optical and chemical data, confirming the reliability of the NOM technique.

The application of NOM demonstrates the ability of plants to respond to variations in light conditions, contributing to a better understanding of their adaptive strategies. The analysis of circadian rhythms, in particular, offers insights into daily oscillations in metabolic activity and their connection to the plants' ability to adapt to changing environmental conditions. Similar findings regarding circadian rhythm fluctuations have been observed by Herppich, von Willert, & Herppich (1995), providing further validation of our observations.

Our study revealed that as transmittance decreased during the day, indicating increased light absorption and CAM activity, total acidity in the leaves significantly increased. This metabolic shift, which aligns with the expected physiological response in CAM plants, was captured in real-time using NOM. The consistency of these results with the chemical analysis highlights the precision of this method.

This work not only confirms the efficacy of NOM for real-time detection of changes in plant metabolism but also allows for more precise determination of optimal

growth conditions regarding light intensity. By using chemical methods to validate NOM results, the data obtained are highly reliable and provide a comprehensive view of plant adaptive mechanisms.

Furthermore, given the controlled nature and complexity of experiments involving CAM physiology, the limited number of samples in our study is in line with the best practices documented in the literature (Haag-Kerwer, Franco, & Luttge, 1992). This emphasizes that our findings are robust despite the limited sample size, and effectively demonstrate the potential of NOM for broader application.

NOM can be used for non-destructive analysis of the metabolism of various plants, including those for which chemical analysis has not yet been performed. This method enables the rapid formation of a database with clear classification of C3, CAM, and dual metabolism, significantly aiding researchers in this field to obtain relevant results more quickly than with traditional chemical methods.

In summary, this research represents a significant advancement in the use of optical methods for plant monitoring, particularly for studying CAM physiology under light stress conditions. The NOM technology opens new possibilities for more efficient monitoring and management of plant health in both natural and controlled environments. The results presented here are of great importance for future research in botany, ecology, and agriculture, paving the way for novel approaches to plant stress detection and resource optimization.

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ADSORPTION KINETICS AND THERMODYNAMICS OF CIPROFLOXACIN FROM AQUEOUS SOLUTIONS BY MAGNETIC IRON OXIDE NANOPARTICLES MODIFIED *MORINGA* PODS

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ABSTRACT

The adsorption process of metal oxide nanoparticles has been studied as an effective means of removing organic and inorganic contaminants from water and wastewater. In this study, iron (III) oxide (Fe_3O_4) nanoparticles were synthesized in the presence of *moringa oleifera* pods (MOP) as an adsorbent for ciprofloxacin (CIP) adsorption. *Moringa oleifera* pod biochar with Fe_3O_4 particles precipitated on the surface of biochar was synthesized by co-precipitation method. The effect of various parameters such as contact time, pH, metal concentration and adsorbent dosage on the removal efficiency was determined. The maximum adsorption capacity of CIP by magnetic *moringa* composite (MMC) was 96.12 mg/g. The Langmuir and Freundlich isotherm equations were used to analyze the equilibrium isotherm data. The adsorption process fit well with the second-order kinetics in all cases, and the Langmuir isotherm equation fitted well with the experimental data.

Keywords: *Moringa Oleifera*, Iron oxide, Ciprofloxacin, Nanoparticles.

INTRODUCTION

Water from rivers and lakes is crucial for life to continue. The way it's utilized and discarded is a global environmental problem (Gleick, 2003). In particular, due to the high susceptibility to pollution of water bodies (Mushtaq, Singh, Bhat, Dervash, & Hameed, 2020), which can be polluted by different sources such as microbial, chemical, physical or biotic factors (World Health Organization [WHO], 2017). The main cause of water pollution is anthropogenic activities and the rapid increase in human population is making

the situation worse (Gleick, 2003). Overcrowded areas, industrial activities, chemicals, debris, hospital sewage contaminated with antibiotics, etc. are just a few examples of the damage done to the planet's water sources (Mushtaq, et al., 2020). There are numerous worries regarding the use of antibiotics, such as ciprofloxacin (CIP), in both surface and drinking water, as they may present a risk to both the environment and human well-being. Long-term toxicity, hormonal interference, and direct harm to microorganisms, even in small amounts, are among these issues. (Yahya, et al., 2014). Ciprofloxacin is a clinically used third-generation fluoroquinolone with potent, broad-spectrum antibacterial activity. Recent research has reported a large number of emerging pollutants whose metabolites have been identified in aqueous media. A number of promising wastewater treatment methods have been used to remove CIP from wastewater, such as: B. membrane separation (Avella, et al., 2010), ozonation (Witte, et al., 2010), Naofiltration (Sun, Hatton, & Chung, 2011), photocatalytic degradation (Van Doorslaer, Demeestere, Heynderickx, Van Langenhove, & Dewulf, 2011), and adsorption (Carabineiro, Thavorn-Amornsri, Pereira, Serp, & Figueiredo, 2012). One of them, adsorption, is considered a promising method for removing CIP (Zhang, Qiao, Zhao, & Wang, 2011), from wastewater in terms of its simple construction, easy operation, large surface areas, developed porous structures, rich functional groups, and high and low adsorption capacity. Various adsorbents including activated carbon, chitosan-metal microparticles (Reynaud, et al., 2011), coal fly ash (Zhang, et al., 2011), kaolinite (Li, et al., 2011), and dioctahedral clay minerals (Wang, Li, & Jiang, 2011).

In this study, the Fe_3O_4 magnetic nanoparticles modified with *Moringa oleifera* pods were prepared using the chemical co-precipitation method. The influences of pH, adsorbent dose, and contact time, CIP initial concentration, and solution temperature on the adsorption capacity were investigated. The adsorption kinetics and thermodynamics were also examined.

EXPERIMENTAL

Material and Methods

Collection and Preparation of *Moringa Oleifera* Pods

Moringa oleifera pods were collected from trees in Limpopo farm near Polokwane. Soon after collection, pods were washed thoroughly with doubly distilled deionized water to remove water soluble impurities and oven dried at 105°C for 24 hours. The washed and dried material was pulverized (by mortar and pestle) and sieved to different mesh sizes. The sieved material was rewashed thoroughly with doubly distilled deionized water to remove the fine particles and dried at 105°C for 4 hours. The material was treated with 0.1M nitric acid and methanol for 4 hours to remove inorganic and organic matter from the sorbent surface and dried in an electric furnace. The treated and untreated materials were then placed in a desiccator to be used as sorbents.

Batch biosorption experiments were conducted to investigate the influence of physiochemical parameters such as contact time, initial concentration, adsorbent dosage, and temperature on CIP adsorption. Batch experiments were performed for different CIP concentrations (10 - 60 mg/L), temperature (14 - 50°C), adsorbent dose (0.1- 0.6 g/L) and contact time (0 - 180 min). After prescribed contact time, the solution was filtrated using filter syringe and the concentration of CIP in the filtrate was measured using UV-Vis.

Preparation of the iron oxide magnetic nanoparticles, biochar, and composite

The Fe_3O_4 magnetic nanoparticles (MNP) were prepared from a 400mL solution of $FeCl_3$ (7.8 g, 28 mmol) and $FeSO_4$ (3.9 g, 14 mmol) at room temperature using the chemical co-precipitation method (Oliveira, et al., 2003). The solution was continuously stirred with an overhead stirrer while 1.0M NaOH solution was added dropwise to precipitate the MNP. The MNP was magnetically separated, washed with water and then ethanol before drying. The mass of MNP after drying was noted.

The pulverized *moringa* pods (PMP) was separately charred in a crucible at 250°C for 4 hours to obtain the *moringa* biochar

(MBC). The biomass was first dried at 110°C for 1 hour before increasing the temperature at a rate of 5°C.min^{-1} until 250°C which was maintained for 4 hours. The PBC was then cooled, ground, sieved through a 230 mm mesh size sieve. This was followed by washing until the filtrate was colourless indicating no leaching of residual Fe or carbon. The MBC was again dried at 105°C for 2 hours, cooled, weighed noted, and stored.

The MBC-MNP combo (MMC) was prepared by calcining the treated *moringa* pods (MOP) and MNP. The MNP was prepared by chemical co-precipitation in the presence of the treated MOP and subsequently calcined at 250°C. Typically, the MOP was suspended in a 400 mL solution of $FeCl_3$ (7.8 g) and $FeSO_4$ (3.9 g) and stirred thoroughly to allow for wetness. A solution of 1.0M NaOH solution was added dropwise to raise suspension pH to 10 and precipitate the MNP on the MOP surface. The solution was further stirred for 30 min before separation by centrifugation at 2500 rpm for 4 min. followed by filling of the residue into a crucible for the calcining process. The crucible was heated at 110°C for 1 hour before raising the temperature at a rate of 5°C/min until 250°C which stood for 4 hours. After the calcining process, the MMC combo was cooled and washed with water until the filtrate was colourless indicating no leaching of organic matter or iron. The MMC was subsequently dried at 105°C for 2 hours and stored.

Data Management.

Adsorption capacity (mg. g^{-1}) at equilibrium for adsorption of analyte were determined by equation 1.

$$q_e = \frac{(C_0 - C_e)}{M} V \qquad (1)$$

where Co and Ce are the initial and final pollutant concentrations (mg/L), respectively, while M (mg) and V (mL) are the MMC mass and solution volume, respectively.

Adsorption Isotherm of MMC

Langmuir and Freundlich adsorption isotherm models were used to depict the equilibrium between adsorbed CIP on MMC (q_e) and CIP concentration in solution (C_e) at constant temperature (30 °C).

Kinetic Study of MMC

The pseudo-first order and pseudo-second order kinetic models were used to describe the adsorption process.

Thermodynamic Parameters

Thermodynamic parameters such as Gibbs free energy (ΔG), enthalpy (ΔH) and entropy (ΔS) for the adsorption of cations on MMC are calculated using the following equations (Machado, Lazarin, & Airoldi, 2006; Guerra, Lemos, Airoldi, & Angelica, 2006):

$$\Delta G = -RT\, InK_L$$

where K_L is the equilibrium constant obtained from Langmuir model, T the absolute temperature (K) and the universal gas constant R=8.314×10^{-3} kJK^{-1}mol^{-1}. The relationship between K_L and thermodynamic parameters of ΔH and ΔS can be described by the Van't Hoff correlation in the following equation (Celik, & Ozdemir, 2018; Yildiz, Erol, Aktas, & Alimli, 2004):

$$InK_L = \frac{\Delta S}{R} - \frac{\Delta H}{RT}$$

The thermodynamic study was made at three different levels of temperatures which were 298, 313 and 343 K.

Sample preparation for FTIR analysis

An approximately amount of 150 mg of potassium bromide (KBr) was mixed with about 1 mg of the sample. The mixture was crushed using pestle and mortar, thereafter a small amount of the crushed fine powder was loaded into three pieces of the pellet press using spatula. The three pieces of the pellet press was transferred to hydraulic press for compression for about 2 minutes. The resulted pellets were introduced into FTIR instrument for analysis. The experimental

condition for FTIR analysis (Bruker-Alpha, Germany), the scan range was 400 – 4500 cm^{-1}.

Scanning Electron Microscope (SEM)

Scanning electron microscopy (SEM) was used to observe the microstructure and surface morphology of MOP and MMC. The SEM images were obtained on a Cerl-Zeiss Sigma instrument (Germany) that uses a tungsten filament source. The samples were Pd-Au coated and imaging was done at 5 kV.

Thermogravimetric Analyser (TGA)

The TGA normally require no sample preparation. In this study an approximately amount of 10 mg of the sample was loaded into TGA ceramic crucible and introduced to TGA instrument for analysis. Table 1 below shows experimental conditions for TGA analysis.

Table 1: Experimental set up conditions for TGA analysis.

Instrument's name	**Hitachi-STA7200RV, Japan**
Parameters	
Temperature range	30-650 °C
Nitrogen flow	20 ml/min
Heating rate	10 °C/min
Holding time	3 min

RESULTS AND DISCUSSION

Fourier transform infrared spectrometry (FTIR)

The main functional groups responsible for adsorption present in the magnetic iron oxide nanoparticles modified with *Moringa oleifera* pods, were characterized by infrared analysis. The FTIR spectra were recorded in transmittance band mode in the wavelength range from 4400 cm^{-1} to 400 cm^{-1} as shown in Figures 1 and 2.

Using FTIR, it's possible to verify whether various pollutants can effectively be adsorbed onto MOP, achieving both adequate and satisfactory removal rates. As shown in Figures 1 and 2, the FTIR spectroscopic analysis indicated band at 3326 cm^{-1}, representing bonded – OH groups.

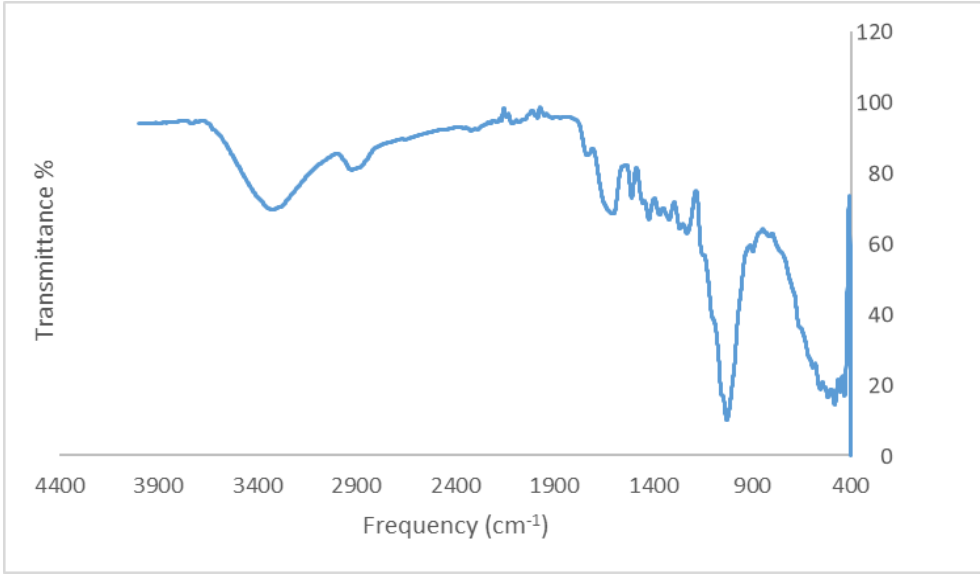

Figure 1. FTIR spectrum of *moringa oleifera* pods.

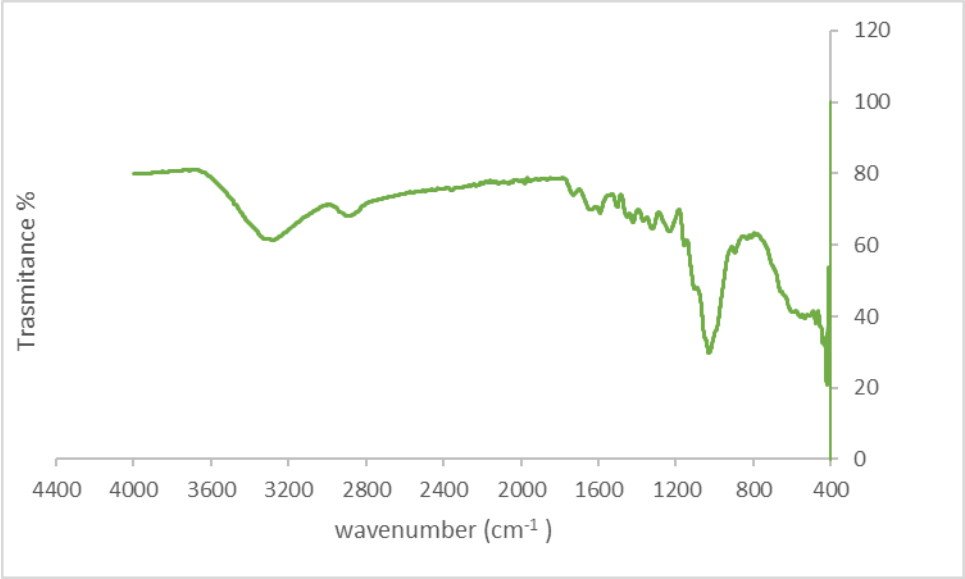

Figure 2. FTIR spectrum of magnetic *moringa oleifera* pods.

The band observed at 2917–2849 cm^{-1} was assigned to the aliphatic C–H group. The peak around 1623 cm^{-1} corresponds to C=O stretch. The peak observed at 1541 cm^{-1} corresponds to the secondary amine group, while the peak at 1374 cm^{-1} corresponds to the symmetric bending of CH_3; the one observed at 1314 cm^{-1} corresponds to the C–H bending. Also, the peak observed at 1242 cm^{-1} corresponds to the $–SO_3$ stretching, at 1029 cm^{-1} corresponds to C=O bonds of ether, ester or phenol, at 668 cm^{-1} corresponds to –CN stretching, while the peak observed at 564 cm^{-1} corresponds to S–O. On the other hand, typical functional groups for iron oxide are depicted by absorption band at 3660 cm^{-1} that corresponds to the hydroxyl functional group and a band obtained at 531 cm^{-1} is characteristic of $M_{tetrahedral}$ resonance with O (Kandpal, Sah, Loshali, Joshi, & Prasad, 2014). This peak also relates to Fe-O group.

Scanning Electron Microscope (SEM)

The SEM images (Figures 3(a-b)) were evaluated to study the surface morphology of the adsorbents prior to adsorption of CIP. The SEM images of the MOP biomass were inherently foamy and fibrous with no particular shape as reported elsewhere (Tavengwa, Cukrowska, & Chimuka, 2016). However, after thermal treatment (250°C), the surface morphology showed macropores and irregular trough-like patterns. The structure appeared weak and the cell morphology of the vegetable biochar was absent. The micrographs of MOP (Figure 3(a)) shows mesoporous structures with different pore sizes. These surface properties would result in high CIP binding due to the available binding voids for the CIP. The porosity for the magnetic *Moringa* composite has improved compared to the modified MOP. Therefore, this can explain the difference in the adsorption capacity of CIP using these adsorbents. As also shown, the magnetite composite appears to be agglomerated, which could be attributed to strong binding of nanoparticles, magnetic dipoles as well as van der Wall forces (Ehrampoush, Miria, Salmani, & Mahvi, 2015). Under these circumstances, one can deduce that dispersing the adsorbent particles before using them in the adsorption process is a necessary step to take full advantage of the particle surface area (Nasseh, Al-Musawi, Miri, Rodriguez-Couto, & Hossein-Panahi, 2020).

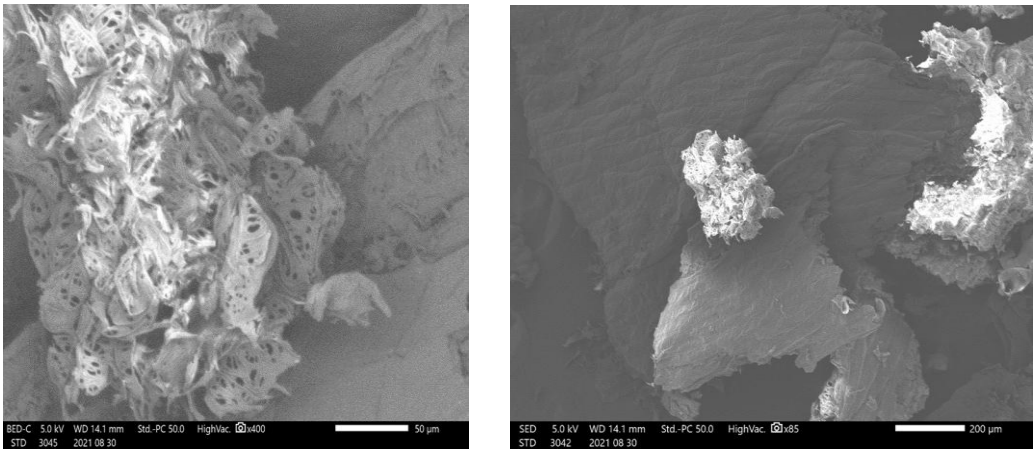

Figure 3. SEM images: (a). MOP before adsorption, (b). MMC before adsorption

Thermogravimetric Analyser (TGA)

The thermal stability of MMC was examined when MMC was heated from 20.5°C to 800°C as shown in Figure 4. The various thermal decomposition states in terms of percent weight loss and their respective derived weight loss percentages per C were reported by Araujo, et al., (2010). The first stage between 20°C and 100°C involves water loss, or the water desorption process occurs during the initial phase of decomposition. The second stage between 100 °C and 350 °C could be due to the loss of organic matter, which could contain amino acid residues from proteins with different functional groups and other low molecular weight compounds. The third stage between 350°C and 780°C could consist of higher boiling point compounds. At the end of the decomposition stage (780° C), the total residue was thus reached.

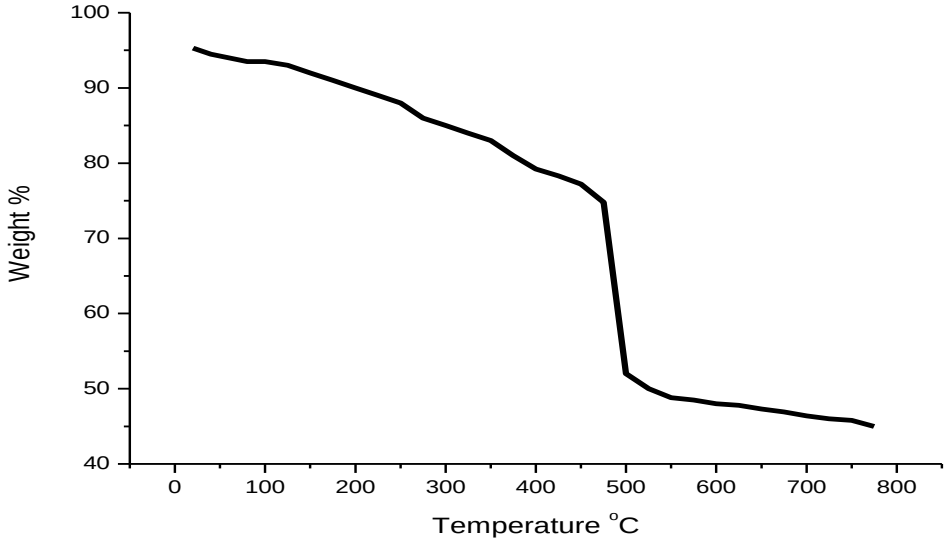

Figure 4. TGA curve for MMC

Effect of biosorbent dose

The influence of the adsorbent dose (0.1- 0.6 g/L) at an initial CIP concentration of 10 mg/L was tested at 30°C. As shown in Figure 5, the results show that the CIP removal rate increased sharply with increasing adsorbent dose (from 0.1 to 0.2 g/L) and then more slowly from 0.2 to 0.6 g/L increased. This result may be due to the increase in the number of adsorption sites and the increase in surface area with increasing amount of adsorbent. Therefore, 0.3 g/L of the adsorbent dose was used in subsequent experiments.

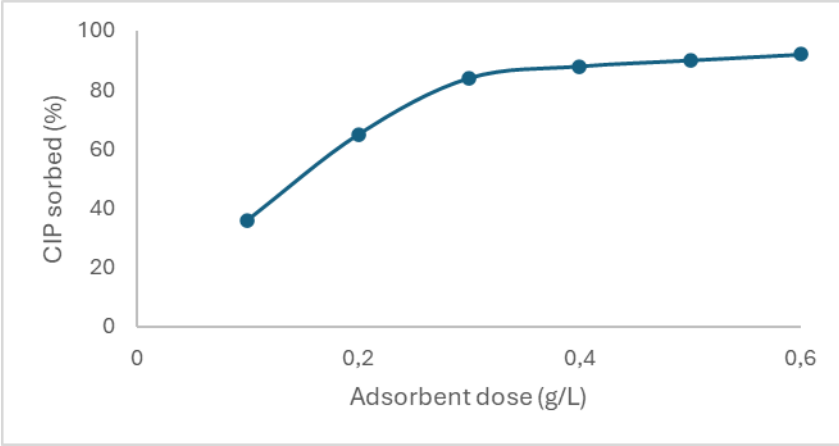

Figure 5. Effect of adsorbent dose for the adsorbent on adsorption removal

Effect of contact time

The effect of contact time is one of the important parameters that helps determine the equilibration time as well as provide insight into the sorption rate and mechanism. The results obtained, Figure 6, showed that the adsorption rate was high during the first 60 minutes, reaching about 85% of the total CIP sorbed by MMC. After 60 min the sorption rate was relatively slow, there were numerous available active sites on the adsorbent surface. As the sites were occupied, the rate of adsorption gradually decreased (Kakavandi, Esrafily, Mohseni-Bandpi, Jafari, & Kalantary, 2013). Adsorption reached equilibrium at 120 min for MMC. A contact time of 180 minutes was therefore chosen for further tests.

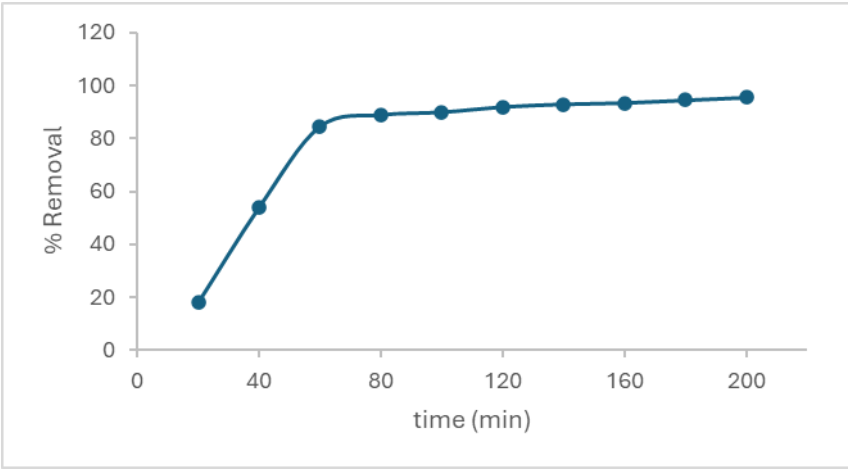

Figure 6. Effect of contact time on CIP removal

Effect of pH

In a broader context, the pH level of a solution is regarded as a significantly impactful variable that determines the adsorption process. It has been found that pH affects the surface charge of the adsorbent, Figure 6 shows the effect of pH on CIP adsorption. The results show a higher rate of CIP adsorption removal in the range of pH 6-9. For CIP, the acid dissociation constants are 6.1 for the carboxylic acid group (pK_{a1}) and 8.7 for the basic N-unit (pK_{a2}) (Gu, & Karthikeyan, 2005). Therefore, CIP molecules exist mainly as cations at pH < 6.1 due to protonation of the amine group. At pH > 8.7, CIP molecules exist as anions due to deprotonation of carboxylate. At a pH in the range of 6.1 to 8.7, CIP molecules exist as zwitterions. In addition, the PZC of the adsorbent is pH 7.3. Therefore, if the solution has a pH < 7.3, the adsorbent surface will be positively charged; however, at pH > 7.3 the adsorbent surface becomes negatively charged. Accordingly, the electrostatic interaction between charged CIP molecules and the charged adsorbent surface at pH < 6 and pH > 9 (Figure 7) is optimal conditions for the adsorption process. At pH in the range of 6-9, the CIP molecules and the adsorbent surface have opposite charges, resulting in a high removal rate of adsorption pH < 6 and pH > 9.

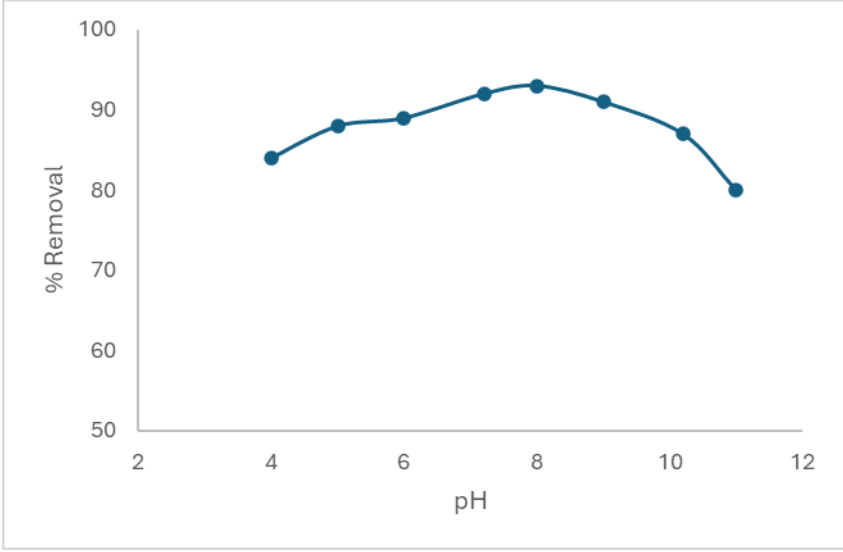

Figure 7. Effect of pH for the adsorbent on adsorption removal

Initial metal concentration

The initial concentration provides a significant driving force to overcome the total mass transfer resistance of CIP between the aqueous and solid sorbent. The effect of the initial CIP concentration is shown in Figure 8. CIP adsorption capacity increased with increasing initial CIP concentration. Figure 8 also shows that the rate of CIP removal decreased as the initial concentration increased from 10 to 60 mg/L. This may be due to the limitation of available free space on MMC for CIP adsorption.

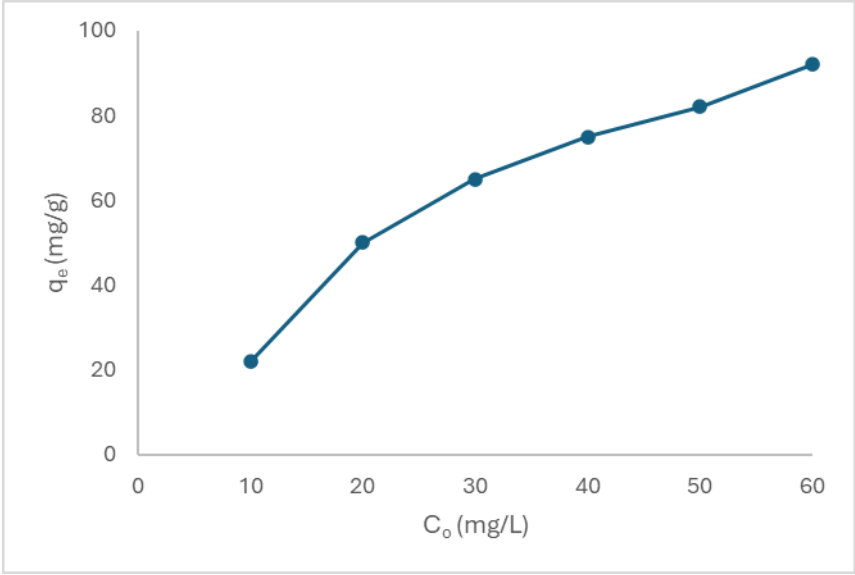

Figure 8. Effect of initial CIP concentration for MMC on adsorption capacity

Effect of temperature

The effect of temperature on CIP adsorption is shown in Figure 9. As shown in the figure, the adsorption capacity increased with increasing temperature, indicating that the adsorption is endothermic. This trend shows that increasing the temperature is beneficial for adsorption. Increasing the temperature increases the mobility of CIP towards the sorbent and can also cause a swelling effect within the internal structure of the sorbent and therefore allow the CIP to penetrate further or increase the surface area for CIP to bind.

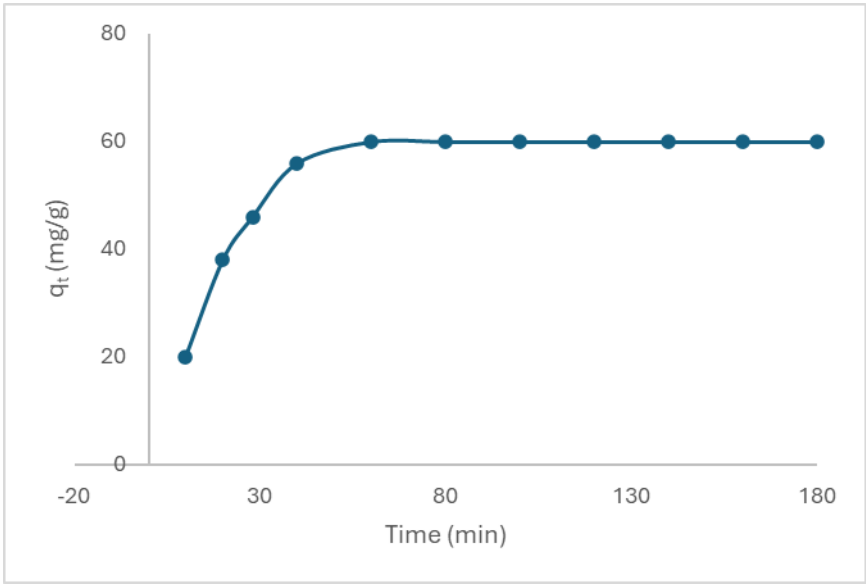

Figure 9. The effect of temperatures on adsorption capacity

Adsorption isotherms

The adsorption isotherms were fitted by the Langmuir and Freundlich models. Table 2 shows the obtained sorption isotherm constants for magnetic *Moringa* biosorbent according to the Langmuir and Freundlich models. We can observe that the Langmuir model is more suitable for describing the adsorption process than the Freundlich model. Therefore, we can assume that the CIP adsorption occurs mainly by monolayer adsorption. The theoretical maximum adsorption capacity is 96.12 mg/g at 30 °C.

Table 2. Langmuir model and Freundlich model parameters.

Langmuir Model				Freundlich Model		
q_{max}	K_L	R_L	R^2	k_F	n	R^2
96.12	0.109	0.096	0.995	12.77	1.75	0.881

Kinetic study

The kinetic studies and the modeling of the experimental data are presented in Figure 10 and certain parameters are listed in Table 3 for models, it is verified that both models fit the experimental data well. Correlation parameters for the adsorption kinetics in the two models are shown in Table 3. As shown, the CIP adsorption on the adsorbent fits well with the pseudo-second-order kinetic model (R^2 = 0.992). This fit implies that the adsorption process occurs through chemical adsorption involving valence forces or electron exchange between CIP and the biosorbent, while the pseudo-first-order model assumes the occurrence of adsorption through physisorption.

Table 3. Obtained parameters of kinetics models for adsorption on MMC

Pseudo-first-order				Pseudo-second-order			
k_1	$q_{e.cal}$	$q_{e.exp}$	R^2	k_2	$q_{e.cal}$	$q_{e.exp}$	R^2
0.0897	4.74	9.712	0.949	0.0063	11.231	9.712	0.992

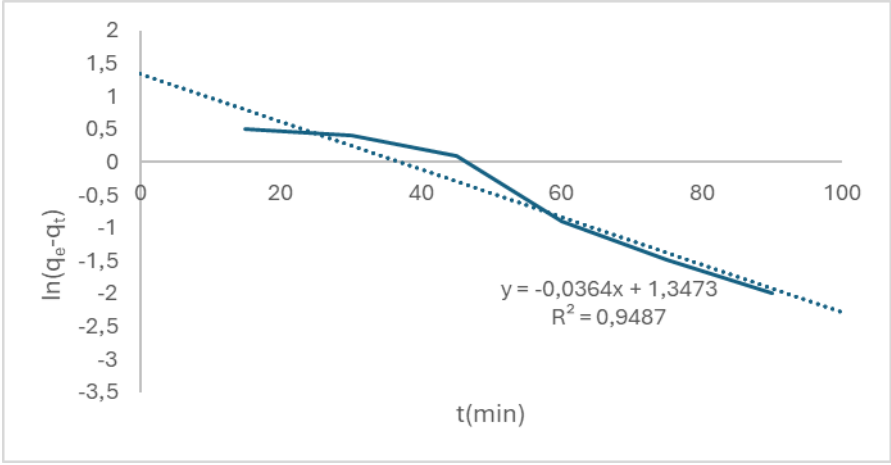

Figure 10(a). The analysis of determination of PFO of CIP adsorption onto MMC

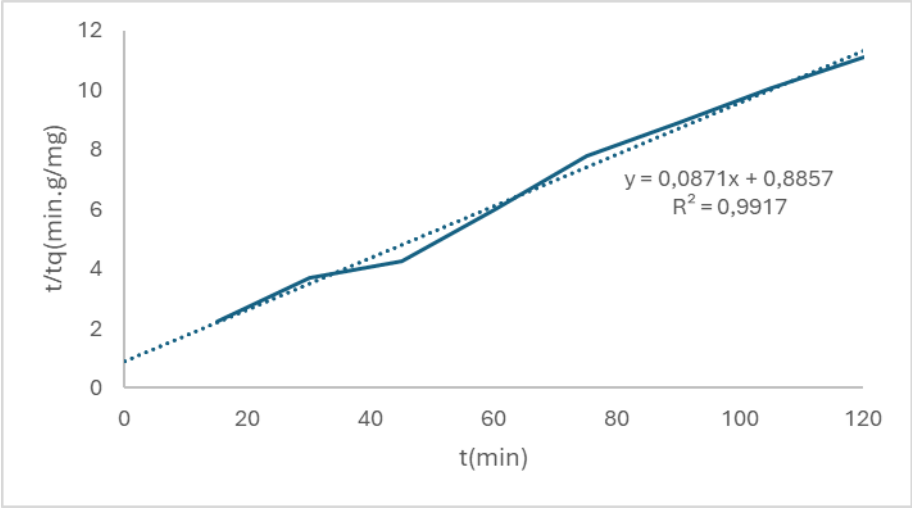

Figure 10(b). The analysis of determination of PSO of CIP adsorption onto MMC

The pseudo-second-order kinetic model, which best fits the experimental data in this study, had the highest correlation coefficient. A preliminary comparison in terms of adsorption rate (q_e) between the calculated and experimental values can be made to prove the best agreement, since the values calculated by the pseudo-second-order kinetic model are closer to the experimentally obtained ones. Such results demonstrate chemisorption reactions of adsorption of CIP molecules onto MMC (Pan, et al., 2011; Mohammed, Al-Musawi, Kareem, Zarrabi, & Al-Ma'abreh, 2020).

Adsorption thermodynamics

Results of thermodynamic parameters, which depend on the calculation of the temperature study, affect the nature of the adsorption process between adsorbent and adsorbate, be it physical or chemical adsorption (Zhang, et al., 2011; Erşan, Bağda, & Bağda 2013). The thermodynamic parameters are listed in Table 4. The negative values of ΔG° indicated that the adsorption performance of CIP on the MMC was feasible and spontaneous. Furthermore, the absolute values of ΔG° decreased with increasing temperature, indicating that the presence of a low-temperature energy barrier in adsorption and high-temperature adsorption was favorable (Balarak, Mahdavi, Bazrafshan, & Mahvi, 2016). The positive values of ΔH° confirmed the endothermic nature of the adsorption process, while the positive values of ΔS° indicated that the randomness at the solid-solution interface increased during the adsorption process (Balarak, & Azarpira, 2016).

Table 4. Thermodynamics parameters for CIP adsorption by MMC

T (K)	ΔG° (kJ/mol)	ΔH°(kJ/mol)	ΔS° (J/mol/K)
288	-3.37		
303	-4.84	3.07	0.03
323	-5.63		

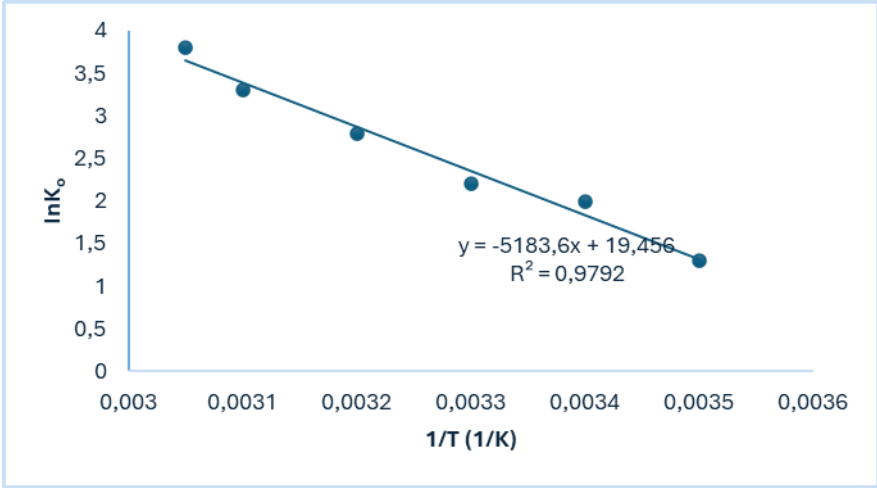

Figure 11. Graph of ln K vs. 1/T for the estimation of thermodynamic parameters of biosorption of CIP by MMC

Comparison with other adsorbents

Table 5 shows the determined maximum adsorption capacities for CIP using the current adsorbent and other materials tested in previous studies. Based on these results, the MMC used in the present study showed a high adsorption capacity for removing CIP molecules from aqueous solution compared to other adsorbents.

Table 5. shows the adsorption capacities of CIP on various sorbents

Adsorbent	Maximum adsorption capacity (mg/g)	Reference
Fe-pillared clays	122.1	(Roca Jalil, Baschini, & Sapag, 2017)
Magnetic activated carbon/chitosan	90	(Danalıoğlu, Bayazit, Kuyumcu, & Salam, 2017)
Cupric oxide nanoparticles	73.86	(Ahmadi, Banach, Mostafapour, & Balarak, 2017)
Magnetic mesoporous	98.3	(Shi, Fan, & Huang, 2013)
ZnO nanoparticles	8.3	(Dhiman, & Sharma, 2019)
Magnetic chitosan-grafted GO	282.9	(Wang, et al., 2016)
Current study	96.12	

CONCLUSION

The removal of the antibiotic ciprofloxacin (CIP) from aqueous solutions was thoroughly investigated in the current study using *Moringa oleifera* pods magnetized with magnetic iron (III) oxide (Fe_3O_4) nanoparticles. First, the used adsorbent was synthesized by the co-precipitation method. The characterization techniques like Fourier transform infrared spectrometry, thermogravimetric analyser and scanning electron microscope potential were used to identify different functional groups responsible for the adsorption, thermal stability and morphology of the nanoparticles. The Fourier transform infrared spectrometry confirmed different functional groups such as amine/amide, carbonyl, hydroxyl, carboxyl and iron oxide on modified magnetic iron oxide nanoparticles, which could be responsible for the selective recovery of ciprofloxacin. The scanning electron

microscope revealed a porous morphology with different pore sizes, which could be responsible for the retention of ciprofloxacin. The study also showed that the synthesized magnetic *moringa* composite (MMC) had excellent morphological properties, super paramagnetic value and brilliant active groups. The thermodynamic study showed that the ciprofloxacin adsorption was favorable, spontaneous, and endothermic. The results showed that the Langmuir isotherm and pseudo-second-order kinetic models were the best to describe the experimental isotherm and kinetic data of ciprofloxacin adsorption onto magnetic *moringa* composite.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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SEQUESTRATION OF CIPROFLOXACIN FROM AQUEOUS SOLUTIONS BY NANOCOMPOSITE OBTAINED VIA *MORINGA OLEIFERA* PODS AND FELDSPAR CLAY MODIFICATION

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ABSTRACT

The environmental hazards of antibiotics have captivated increasing research focus, but their environmental behaviours remain unclear in water sources. Thus, this study focused on exploring the interaction mechanisms between *Moringa Oleifera* pod-modified feldspar clay (MFC) and ciprofloxacin (CIP) during sorption process. The efficiency of these adsorbents in aqueous solution adsorption of CIP were investigated as a function of pH, time and sorbate concentration. The impact of pH solution and CIP evolution showed that CIP sorption on MFC is strongly reliant on pH solution. Kinetic studies authenticated that the CIP sorption mechanism was a physisorption involving ion exchange and surface complexation mechanisms. The mechanism of CIP sorption on MFC was successfully studied using characterization techniques. The Langmuir and Freundlich isotherm equations were used to analyze the equilibrium isotherm data. The adsorption process fitted well with the second-order kinetics and the Langmuir isotherm equation fitted well with the experimental data. The Langmuir isotherm showed that maximum adsorption capacity was found to be 57.61 mg. g^{-1}. Thermodynamic factors: $\Delta G°$ values of -29 $kJ.mol^{-1}$, $\Delta H° = 17$ $kJ.mol^{-1}$, and $\Delta S° = 163$ $J.mol^{-1}$ k of CIP adsorbed onto MFC indicate that the adsorption was spontaneous and endothermic in nature.

Keywords: *Moringa Oleifera*, Carbonaceous materials, feldspar clay, Ciprofloxacin, Sorption

INTRODUCTION

Due to the potential harm to the environment and the effects on the health of people and animals, there is a great deal of concern about the removal of pollutants from

aquatic ecosystems. Anything that is present in the aquatic environment at a negligible concentration and whose presence is not entirely certain is considered an emerging contaminant (EC) (Rodriguez-Narvaez, Peralta-Hernandez, Goonetilleke, & Bandala, 2017). Antibiotics are commonly used to treat bacterial illnesses in human therapy and as veterinary drugs to forestall illnesses in livestock, and also feature as increase promoters, normally in farm animals (Kümmerer, 2009). With the high rate of different antibiotics in use, extensive amount of pharmaceutical wastewater containing antibiotics has been acquitted into the surroundings (Hartmann, Golet, Gartiser, Alder, & Koller, 1999), they are also not definitely digested in the human/animal body, but emanated by way of urine, animal dung and/or faeces. Ciprofloxacin (CIP), one of the most generally used antibiotics in the therapy of infectious diseases (Martins, Vasconcelos, Henriques, Frank, König, & Kümmerer, 2008; Hartmann, Alder, Koller, & Widmer, 1998; Hartmann, 1998), is not comfortably biodegradable (Hirsch, Ternes, Haberer, & Kratz, 1999) and has extreme toxic aspect consequences such as stomatitis, leukopenia and emesis in humans (Kümmerer, Al-Ahmad, & Mersch-Sundermann, 2000; Cox, et al., 2002). Excessive occurrence of CIP in the marine environment can also yield an increase in antibiotic-resistant bacteria (Diwan, et al., 2010) and adverse effects on water quality (Chang, et al., 2010).

However, less studies have dealing at the eradication of CIP from water correlate to other antibiotics. Considerable strategies have been utilized for CIP elimination, including chemical oxidation and electrochemistry (Xiao, Zeng, & Lemley, 2010), oxidation by chlorination (Li, & Zhang, 2012), ozonation (Nasuhoglu, Rodayan, Berk, & Yargeau, 2012), photolytic and photocatalytic treatment (Vasquez, Hapeshi, Fatta-Kassinos, & Kümmerer, 2013), Photo-Fenton oxidation processes (Sun, et al., 2009), and enzymatic degradation and biological treatment (Dorival-García, Zafra-Gómez, Navalón, González, & Vílchez, 2013), and adsorption (Chen, Gao, & Li, 2015; Maged, Kharbish, Ismael, & Bhatnagar, 2020). To a certain extent these techniques are notorious for their high cost of implementation or poor ability to achieve respectable water quality, with the exception of adsorption. Thus, biological materials, nanomaterials and clays have all been explored as low-cost adsorbents for the elimination of antibiotics from aqueous solutions and wastewaters.

Studies have exemplified different methods of Ciprofloxacin (CIP) removal from the water systems. Acid-activated bentonite clay mineral has been used to evaluate the interaction of nanocomposites with ciprofloxacin (CIP) during sorption process from aqueous solution (Maged, et al., 2020). In this time consuming work the maximal monolayer sorption capacity of 305.20 mg. g^{-1} was observed, while effect of CIP speciation and the pH value of solution demonstrate that CIP sorption onto bentonite is greatly dependent on pH value, and sorption mechanism as chemisorption as revealed by the kinetic studies. Fluoroquinolone antibiotic levofloxacin (LEVO) in water was removed by ozonation and photo catalysis (UVC lamp (254 nm), TiO_2) (Nasuhoglu, et al., 2012). It was observed that after an ozone dose of 20.5 mg/L and 180 min of photocatalytic oxidation, LEVO at initial concentration (Co = 20 mg/L) was no longer detected.

Ciprofloxacin hydrochloride was effectively degraded by Photo-Fenton oxidation process under optimum conditions of $C_0 = 15$ mg/L, pH 4.0, $[Fe^{2+}] = 0.05$ mmol/ L, $[H_2O_2] = 5.0$ mmol/L, and 25°C, it was observed that in the 45-min reaction time, no ciprofloxacin hydrochloride was detected. It was determined that the degradation kinetics of ciprofloxacin hydrochloride by this process followed the first-order reaction kinetics model (Sun, et al., 2009). The capability and mechanism of graphene-oxide to remove ciprofloxacin (CIP) and sulfamethoxazole (SMX) from aqueous solution was reported to effectively adsorb both sulfamethoxazole and ciprofloxacin with maximum sorption capacity of 240 and 379 mg/g, respectively (Chen, Gao, & Li, 2015). Commonly found quinolones (ciprofloxacin, norfloxacin, pipemidic acid, moxifloxacin, piromidic acid,

and ofloxacin), in wastewaters from a wastewater treatment plant, were removed by sorption and biological degradation in laboratory-scale membrane bioreactors (MBR) pilot plant (Dorival-García, et al., 2013). Sorption on the sludge played a prevailing role in the elimination of the antibiotics from waters as indicated by mass balances. In this investigation it was estimated that the sorption coefficient K_d values were between 516 and 3746 L/kg within temperature range of 9–38 °C.

The study focuses on a composite of *Moringa oleifera* pod and feldspar clay, which is one of many natural adsorbents. Synergistic combinations of feldspar clay (FLC) and *Moringa oleifera* pod (MOP) (both low-cost adsorbents) were achieved in this study by associating individual properties of each composite to yield a superior adsorbent with properties such as high cation exchange capacity, bleeding elimination, increased mechanical strength and higher adsorption efficiency for water treatment. After full characterization of the adsorbent, the effect of solution pH, adsorbent dose and contact time on the adsorption capacity was investigated. The adsorption kinetics and thermodynamics were also studied.

EXPERIMENTAL

Materials

All used chemicals were of analytical grade. Ciprofloxacin hydrochloride (CIP) with a purity higher than 99.6% was purchased from Sigma-Aldrich. Ultrapure water purified in a Milli-Q system (pH 7 ± 0.2) was used for this study.

Preparation of Feldspar Clay

Feldspar clay (FLC) was obtained from the clay reserve of Federal Institute of Industrial Research Oshodi (FIIRO), Lagos, Nigeria. The clay was pre-treated by suspending in deionized water in order to remove sand and heavy non-clay materials. Organic matter in the clay was then removed by treatment with 30% hydrogen peroxide (H_2O_2) solution (Diagboya, Olu-Owolabi, & Adebowale, 2015). This was followed by washing with distilled water, drying at 105°C, sieving using a mesh size sieve, and stored.

Collection and Preparation of *Moringa Oleifera* Pods

Moringa oleifera pods (MOP) were collected from trees in Limpopo farm near Polokwane. Soon after collection, pods were washed thoroughly with doubly distilled deionized water to remove water soluble impurities and oven dried at 105°C for 24 h. The washed and dried material was pulverized (by mortar and pestle) and sieved to different mesh sizes. The sieved material was rewashed thoroughly with doubly distilled deionized water to remove the fine particles and dried at 105°C for 4 h. The material was treated with 0.1M nitric acid and methanol for 4 h to remove inorganic and organic matter from the sorbent surface and dried in an electric furnace. The treated and untreated materials were placed in a desiccator to be used as sorbents.

Preparation of *Moringa Oleifera pod* and Feldspar Clay Composite

Equal weight of FLC and MOP (5.0 g each) were weighed into a 250 m beaker, containing 300 mL of 0.1 M NaOH solution. The content was thoroughly stirred and heated in an oven at 105°C until dryness. The dried samples mixture was weighed into crucibles and calcined at 300°C in a furnace for 6hrs. The resulting dark powdery material was washed with deionized water to remove all carbon materials on the surface of the composite and was subsequently dried to remove all moisture (Unuabonah, Gunter, Weber, Lubahn, & Taubart, 2013). The dried sample was stored in an airtight container and referred as MFC.

ADSORPTION EXPERIMENTS

Adsorption of ciprofloxacin

Experiments were performed with 250 mL glass Erlenmeyer flasks. Each flask contained 50 mL of CIP solution. A certain amount of adsorbent was mixed with the solution, and the resulting mixture was shaken at 130 rpm and 15 °C in a shaker. The solution pH was adjusted with 0.1 mol/L HCl and 0.1 mol/L NaOH solutions. The CIP concentrations were measured by Ultraviolet–visible spectroscopy spectrophotometry at

271 nm. The adsorption capacity (q_e, mg/g) was calculated through Eq. (1):

$$q_e = \frac{(C_0 - C_e)}{M} V \quad (1)$$

where C_o and C_e are the initial and final pollutant concentrations (mg/L), respectively, while M (mg) and *V* (mL) are the MFC mass and solution volume, respectively. The vials were kept in the dark and were shaken in a rotary shaker at 15 °C for 72 h which was sufficient to reach apparent equilibrium.

Adsorption Isotherm of MFC

The initial CIP concentration was varied from 10 to 60 mg/L. Langmuir and Freundlich for the adsorption isotherm were used to analyse the experimental data.

Adsorption kinetics determination

For the studies on the adsorption kinetics, 0.02 g adsorbent was added to 50 ml of a 10 mg/L CIP solution. The contact time ranged from 0 to 160 min. The flasks were shaken at 130 rpm at a temperature of 15 °C. Pseudo-first order (Eq. (2)) and pseudo-second order (Eq. (3)) models for the adsorption kinetics were used to analyze the experimental data.

$$log(q_e - q_t) = logq_e - \frac{k_1 t}{2.303} \quad (2)$$

$$\frac{t}{q_t} = \frac{1}{k_1 q_{e2}} + \frac{t}{q_e} \quad (3)$$

Where q_e is the mass of CIP adsorbed at equilibrium (mg/g), *qt* is the mass of CIP adsorbed at time *t* (min), and k_1 and k_2 are the pseudo-first order model and the pseudo-second order model rate constants of adsorption.

Adsorption thermodynamics

In order to understand the adsorption process, the three main adsorption thermodynamic parameters, standard free energy (ΔG^0), standard enthalpy (ΔH^0), and standard entropy (ΔS^0), were calculated. The thermodynamic equilibrium constant is approximately equal to the Langmuir adsorption constant (Liu, 2009). The thermodynamic parameters were calculated through the following equations:

$$\Delta G = -RT\, InK_L \quad (4)$$

where K_L is the equilibrium constant obtained from Langmuir model, T the absolute temperature (K) and the universal gas constant $R=8.314\times10^{-3}$ $kJK^{-1}mol^{-1}$. The relationship between K and thermodynamic parameters of ΔH and ΔS can be described by the Van't Hoff correlation in the following equation (Celik, & Ozdermir, 2018; Yildiz, Erol, Aktas, & Alimli, 2004):

$$InK = \frac{\Delta S}{R} - \frac{\Delta H}{RT} \quad (5)$$

Sample preparation for FTIR analysis

An approximately amount of 150 mg of potassium bromide (KBr) was mixed with about 1 mg of the sample. The mixture was crushed using pestle and mortar, thereafter a small amount of the crushed fine powder was loaded into three pieces of the pellet press using spatula. The three pieces of the pellet press was transferred to hydraulic press for compression for about 2 minutes. The resulted pellets were introduced into FTIR instrument for analysis. The experimental condition for FTIR analysis are shown in Table 1.

Table 1 Experimental conditions for FTIR analysis.

Name of the instrument	Bruker-Alpha, Germany
Parameter	
Scan range	400-4500 cm^{-1}

Scanning Electron Microscope (SEM)

Scanning electron microscopy (SEM) was used to observe the microstructure and surface morphology of MOP, FLC and MFC. The SEM images were obtained on a Cerl-Zeiss Sigma instrument (Germany) that uses a tungsten filament source. The samples were Pd-Au coated, and imaging was done at 5 kV.

RESULTS AND DISCUSSION

The major functional groups present in the MOP and FLC were characterized by infrared analysis. In the Figure 1 are given FTIR spectra of *M.Oleifera* pods, FLC and MFC.

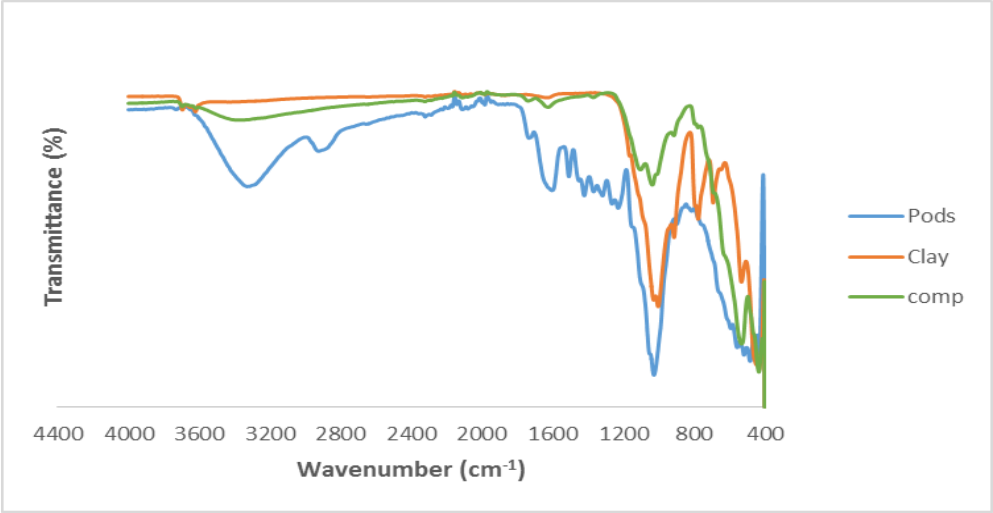

Fig. 1. FTIR spectra *M.Oleifera* pods, FLC and MFC

The broad spectrum centered at 3326 cm^{-1} can be attributed to O-H stretching of the linkage in this protein, fatty acids, carbohydrates and the lignin units. Due to the high protein content of seeds, there is also a relevant contribution to this region because of N-H stretching in amide binding (Stuart, 2004). The peaks appearing at 2970 and 2888 cm^{-1} correspond to asymmetric and symmetric stretching of the C-H to CH_2 group compound, respectively. In the 1800 to 1500 cm^{-1} region there is a series of overlapping bands between 1750 and 1630 cm^{-1}. This set can be attributed to the elongation of the C=O bond. Due to the heterogeneous pod type, the carbonyl group can be attached to different adjacencies as part of the fatty acid portion of the lipid and the protein portion of the amides. The carbonyl occurring at 1741 and 1713 cm^{-1} due to the lipid component, which can be observed in the spectrum as a small peak or shoulder part of the main band at 1656 cm^{-1}, was assigned to the carbonyl amides in the protein portion. The peak at 1585 cm^{-1} can be attributed to the stretching of the C-N linkage and the deformation of the N-H linking proteins present in the seed coat.

The IR spectra of feldspar show a broad amplitude vibration around 1002 cm^{-1}. Furthermore, show vibrations represented by peak between 427 cm^{-1} and 467.30 cm^{-1}, around 693 cm^{-1} and 795 cm^{-1}, around 912 cm^{-1}, 1007 cm^{-1}, 1122 cm^{-1}, 1634 cm^{-1}, 3443 cm^{-1}, 3624 cm^{-1}, 3654 cm^{-1} and 3694 cm^{-1}. As shown in Figure 1, the OH stretching region is between 3805 cm^{-1} and 3408 cm^{-1} (region with strong hydrophilic effect), and the FTIR spectral studies of feldspar show three bands in this region. The extensional vibration mode observed at 1122 cm^{-1}, 1034 cm^{-1}, 1007 cm^{-1} are certainly different vibrational modes of Si-O such as quartz stretching, longitudinal mode and typical extensional mode. The Al-OH-Al bending mode is found at 912 cm^{-1}.

Surface morphology

The SEM images of the MOP biomass were inherently foamy and fibrous with no specific shape as reported elsewhere (Tavengwa, Cukrowska, & Chimuka, 2016). However, after thermal treatment (250°C), the surface morphology showed macropores and irregular gully-like patterns. The structure appeared weak and the cell morphology of the biochar was absent. The

micrographs of MOP (Figure 2) show mesoporous structures with different pore sizes. These surface properties would result in high drug bonding due to the available bonding voids for CIP. Comparing the surface features of FLC and MOP under SEM provides clear differences. The feldspar emerges like a microcrystalline material while MOP appears like a cryptocrystalline material. This manner that between the two adsorbents FLC, MOP, the most crystalline morphology is in FLC although it looks like flakes or plates. MOP has a less crystalline (amorphous) morphology.

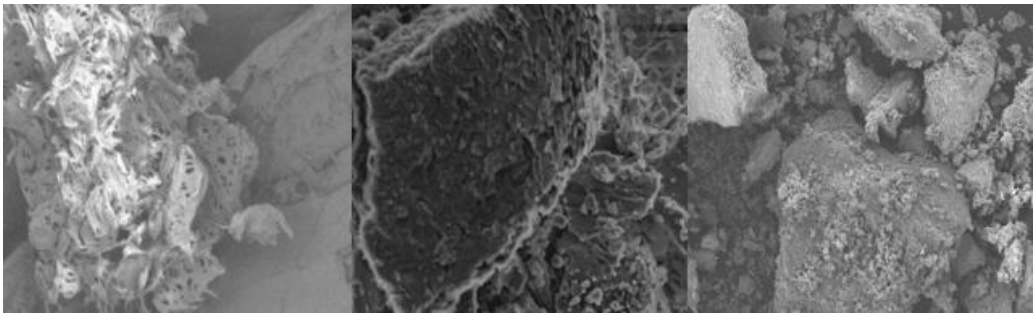

Fig. 2. Scanning electron microscopy images of (A) MOP, (B) FLC and (C) MFC

Effect of adsorbent dose on CIP adsorption

To enhance the quantity of MFC mass essential to achieve utmost CIP sorption, the impact of MFC dosage on CIP elimination efficiency and sorption capacity was evaluated. Sorbent CIP (%) versus adsorbent dosage is plotted in Figure 3. The results obtained showed that the percentage of CIP elimination deliberately elevated with the increase in *Moringa*-clay mass. The surface area and available binding sites increasing could be the cause of this behaviour. The influence of the adsorbent dose (0.1-0.6 g/L) at an initial CIP concentration of 10 mg/L was tested at 15 °C. As shown in Figure 3, the results show that the CIP removal rate increased sharply with increasing adsorbent dose (from 0.1 to 0.2 g/L) and then increased more slowly from 0.2 to 0.6 g/L.

This result may be due to the increase in the number of adsorption sites when the amount of adsorbent increased. This could be attributed to the moringa-clay composite which furnish more surface-active sites for sorption of CIP molecules. Therefore, 0.3 g/L of the adsorbent dose was used in subsequent experiments.

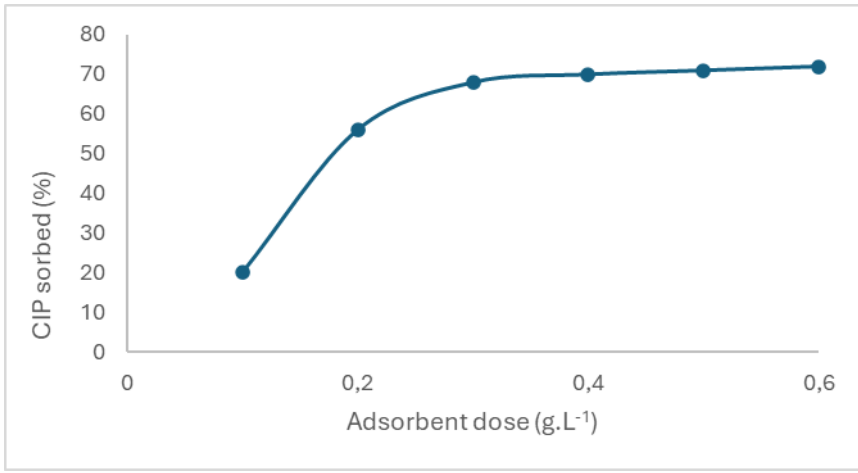

Fig. 3. Effect of adsorbent dose on the CIP sorbed.

Effect of contact time

The percentage of CIP removal increased with increasing contact time (Figure 4). The uptake of CIP was quick in the first 40 minutes and after 60 minutes the amount of CIP adsorbed remained almost constant. Therefore, 60 minutes was chosen as the equilibrium time in the present study. At the beginning of the reaction, adsorption was fast because many vacancies were available (Zhang, Qiao, Zhao, & Wang, 2011). In contrast, the slow adsorption might have been due to insufficient vacancies. The percent adsorption increased from 21.2 to 87.4 over a contact time of 10 to 60 minutes.

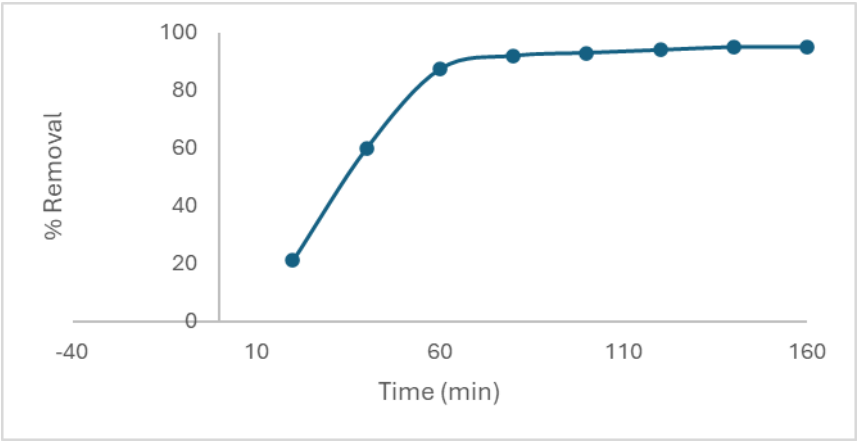

Fig. 4. Effect of contact time on CIP sorbed

Effect of pH

CIP sorption is greatly affected by solution pH due to the different CIP speciation as well as the surface charge of *Moringa*-clay adsorbents. In general, the adsorption of ionizable organic contaminants is influenced by pH due to the different species (Zhang, Pan, Zhang, Ning, & Xing, 2010). CIP has positively charged (cationic), negatively charged (anionic) and/or zwitterionic species at different pH values due to different pK_as (5.9 and 8.9) (Gu, & Karthikeyan, 2005). The cationic CIP form (CIP^+) is present when the pH of the solution is less than pK_{a1} (= 5.9), which is owing to the protonation of the amine group. In acidic and neutral aqueous solutions, a stoichiometric exchange between CIP and interlayer cations resulted in a high adsorption capacity. When the solution pH was above its pK_{a2} (8.7), the adsorption of CIP was significantly reduced due to the net repulsion between the negatively charged surfaces and the CIP anion (Li, Schulz, Ackley, & Fenske, 2010). The widespread use of *moringa* and feldspar clay composite can be associated to its physical and chemical properties such as small particle size, high porosity, large surface area and high cation exchange capacity.

When the pH of the solution is higher than pK_{a2} (= 8.7), the anionic CIP form (CIP^-) exists due to the deprotonation of the amine group. At a solution pH between pK_{a1} and pK_{a2}, the CIP molecule becomes a zwitterion ($CIP^{\pm}$) (Wang, Li, Jiang, Jean, & Liu, 2010). This conduct is owing to the protonation and deprotonation of the amine group and the carboxylic acid group (Jiang, et al., 2013). Figure 5 display the impact of pH solution on CIP sorption by MFC. It was observed that the CIP elimination elevated barely when the pH was less than pK_{a1}, confirming the CIP (cationic form) speciation. Thus, the sorption mechanism of CIP mainly involves cation exchange and interlayer complexation between MFC and CIP molecules. At a pH range of 5–6, CIP sorption was favored due to the electrostatic attraction between negative surface charge of MFC and positive

charge on the CIP molecule. When the pH of the solution is (pK_{a1} < pH < pK_{a2}), the MFC surface becomes negatively charged and the CIP molecules are in zwitterionic form. Hence, positively charged amine groups in zwitterionic form could still donated to CIP sorption through the cation exchange mechanism, and CIP sorption was still high (Genc, Dogan, & Yurtsever, 2013). Subsequently, a sharp reduce in CIP sorption occurred when the pH of the solution became higher than pK_{a2}. This reduction could be explained by the repulsion between the anionic CIP form and the negatively charged *Moringa*-clay surface. The optimal pH has been determined to be 7 since the maximum CIP adsorption capacity occurs.

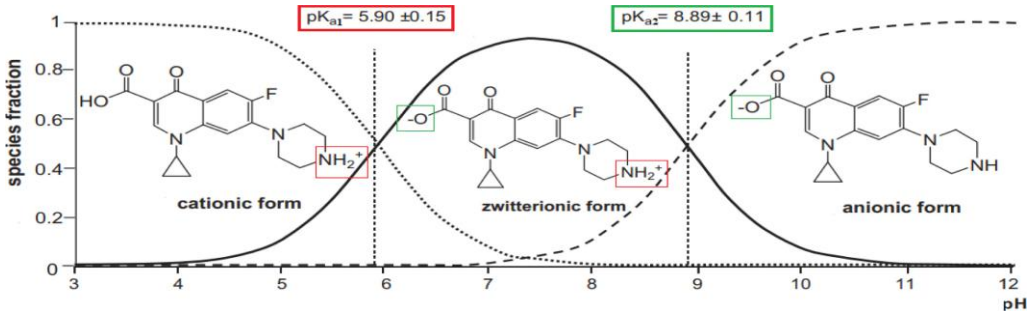

Fig. 5. Molecular structure of CIP and its ionic forms as a function of pH, pK_a values (Carabineiro, et al., 2012)

Adsorption Isotherm of MFC

The isothermic determination of the amount of CIP adsorbed on the surface of an adsorbent can be described by adsorption isotherms. In general, the number of vacant active sites and the pore size on the surface of the adsorbent play a major role in determining the amount of CIP adsorbed. Two adsorption models were applied to the adsorption of CIP on the surface of the MFC: Langmuir and Freundlich isotherms, respectively.

The adsorption isotherm models of Langmuir (Eq. (5)) and Freundlich (Eq. (6)) can be stated as follows:

$$\frac{C_e}{q_e} = \frac{1}{q_m k_l} + \frac{C_e}{q_m} \quad (5)$$

$$\log q_e = \log k_f + \frac{1}{n}\log C_e \quad (6)$$

The Langmuir and Freundlich models are capable of describing the adsorption mechanism on the surface and accounting for these experimental results over a greater concentration range (Juang, Wu, & Tseng, 2010). The adsorption isotherms exhibited linear curves with the highest correlation coefficients (R^2) of 0.97−0.99. The studied parameters, corresponding regression coefficients and constants for each model are listed in Table 2. After a caution resemblance between the model parameters for MFC, Langmuir was shown to be the best fitting model compared to Freundlich with R^2 > 0.98. Furthermore, the calculated maximum sorption capacity (q_{max}) of the Langmuir model and the experimental data values were found in good agreement with the calculated (from the model) values, confirming the validity of this model to describe the CIP sorption process. The Langmuir isotherm also suggested that sorption occurs at distinct homogeneous sites within the adsorbent surface, which is limited to monolayer sorption formation due to strong synergy between the adsorbent and the adsorbate (Rusmin, Sarkar, Liu, McClure, & Naidu, 2015). In the Figure 6 are given the adsorption isotherms of CPI adsorbed by MFC.

Table 2. Langmuir and Freundlich isotherm model parameters for CIP sorption onto MFC

Adsorbent	Langmuir Isotherm			Freundlich Isotherm		
	q_m (mg/g)	K_L x 10^{-3} (L/g)	R^2	n	K_F (L/g)	R^2
MFC	57.61	18	0.9845	1.58	2.29	0.9753

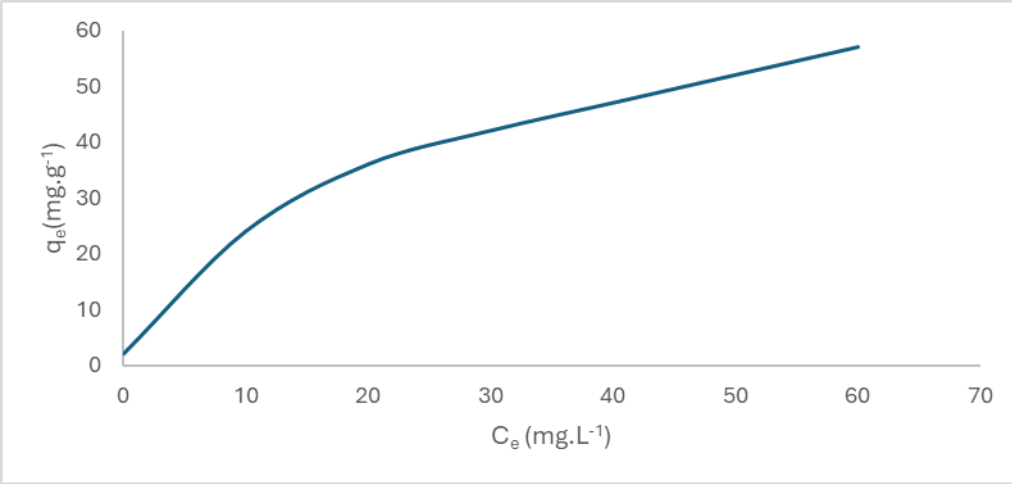

Fig. 6. Sorption isotherms modelling of CIP by Moringa-clay composite

Kinetic Adsorption Isotherm of MFC

In various fields, the pseudo-first order (PFO) and pseudo-second order (PSO kinetic models have been widely used to describe the removal of pollutants from solution (Qiu, et al., 2009). The kinetic adsorption data were adequately suited to the PFO and PSO model (Table 3). The similarity of the two models' kinetic data demonstrated that the CIP sorption process can be adequately described by the PSO model. Strong evidence for this conclusion came from the high R^2 value and good agreement between the experimental($q_{e.exp}$) and calculated sorption capacities($q_{e.cal}$) for MFC that was acquired from PSO (Table 3). As these results demonstrated, the sorption capacity of CIP on MFC via chemical sorption is dependent on the sorption rate and is based on the number of active binding sites on the adsorbents (Duan, Wang, Xiao, Zhao, & Zheng, 2018; Wu, et al., 2019).

Table 3. Pseudo-first order kinetic model and pseudo-second order kinetic model parameters.

Adsorbent	Pseudo-first-order				Pseudo-second-order			
	k_1	$q_{e.cal}$	$q_{e.exp}$	R^2	k_2	$q_{e.cal}$	$q_{e.exp}$	R^2
MFC	0.15	82.70	85.56	0.982	0.0029	87.81	85.56	0.998

The results obtained in Figure 7 showed that the sorption capacity increased rapidly in the first 40 minutes (due to fast sorption), reaching about 85% of the total CIP sorbed by MFC. After 40 minutes the rate of sorption was relatively slow and equilibrium was reached within 120 minutes for MFC.

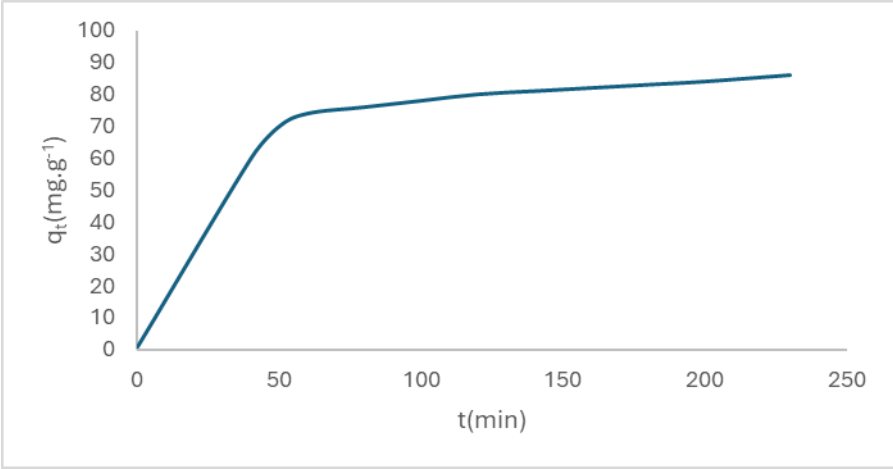

Fig. 7. Modelling of Sorption kinetics for CIP on MFC

Thermodynamics parameters determination

Numerous results can be extracted from the thermodynamic parameters, such as how strongly the adsorbate sticks to the surface of the adsorbent (i.e. chemisorption or physisorption process), exothermic or endothermic processes and entropy changes that occur throughout the adsorption process. The adsorption process is called physisorption when the ΔG° value is around 20 KJ/mol and chemisorption when the value is 80−400 KJ/mol (Wu, et al., 2013). From Table 4, CIP adsorption onto MFC is thermodynamically favourable and spontaneous as seen in the decrease of ΔG° value (Balarak, Mostafapour, & Azarpira, 2015). This is because thermal decomposition promotes the removal of water and other volatile components from the matrices of biomasses (Rocha, Pereira, Sousa, Otero, Esteves, & Calisto, 2020) and subsequent activation results in the formation of temperature-dependent active sites. The enthalpy values suggest CIP adsorption by the biosorbents is a physical process without any chemical change, thus endothermic. This physisorption, as seen in lower ΔH° values (<40 kJ/mol) obtained, is brought about by the covalent bonding between CIP molecules and biosorbent surfaces (Peñafiel, Vanegas, Bermejo, Matesanz, & Ormad, 2019). Finally, the positive ΔS° values imply that there is a rise in the degree of disorderliness and randomness during adsorption. This implies that CIP adsorption leads to disruption of hydration shell surrounding the surface of adsorbents and re-orientation of water molecules around the adsorbents surface will be less ordered.

Table 4. The determined values of thermodynamic parameters

T (K)	b (L/g)	ΔG^0 (kJ/mol)	ΔH^0 (kJ/mol)	ΔS^0 (J/molK)
288	0.19	-29	17	163

In order to assess the efficiency and feasibility of *moringa*–clay composite (MFC) in CIP removal from aqueous solution, it may be appropriate to compare its maximum adsorption capacity value with those reported in previous studies for other adsorbents. A comparison between MFC and other adsorbents with regard to their CIP adsorption capacities is presented in Table 5. According to Table 5, the adsorbents used for the adsorption of ciprofloxacin originated from different natural and synthetic materials.

Moringa-clay composite based on this comparison, has much higher adsorption capacity for CIP than the most of the studied adsorbents, and it can be a good choice as an efficient, low cost and eco-friendly adsorbent.

Table 5. CIP maximum adsorption capacities in comparison with different adsorbents

Adsorbent	Maximum adsorption capacity (mg/g)	Reference
Hazelnut based activated carbon	65	(Balarak, Mostafapour, & Azarpira, 2016)
Bamboo charcoal	36	(Wang, Chen, Ling, & Zhang, 2017)
Raw oat hulls	16	(Movasaghi, Yan, & Niu, 2019)
Synthesized Nanoceria	49.38	(Rahdar, Rahdar, Ahmadi, & Fu, 2019)
Biochar (rice straw)	131.58	(Zeng, et al., 2018)
Silica-pillared clays (Si-PILC 25)	74.5	(Roca-Jalil, Toschi, Baschini, & Sapag, 2018)
Wheat bran	159	(Khokhar, et al., 2019)
Carbon nanosheets supported TiO_2	40.5	(Li, et al., 2019)
Moringa pods-feldspar clay composite	57.61	Current study

CONCLUSION

A potential technique for enhanced removal of aqueous contaminants from solutions is a synergistic combination of inexpensive adsorbents. Well-developed pores from scanning electron microscopy and the observed functional groups from Fourier transform infrared spectroscopy demonstrated the suitability of the adsorbent to remove ciprofloxacin from aqueous solution. The optimal adsorbent dose was determined to be 0.3 g. L^{-1} and the optimal solution pH to be 7. Adsorption was observed to decrease significantly at pH values below 5, the Langmuir isotherm model best describes the adsorption data indicating that the adsorption sites were unevenly and non-specifically. Experimental data were best explained by the pseudo-second-order kinetic model. Thermodynamic studies revealed that the free energy change was negative while the enthalpy and entropy values were positive, indicating that the sorption process is endothermic and spontaneous. This study demonstrates that *Moringa oleifera* pod-modified feldspar clay composite can efficiently remove ciprofloxacin from aqueous solutions.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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ADSORPTION OF HEAVY METALS FROM WATER USING *MORINGA OLIFERA* PODS MODIFIED WITH IRON OXIDE NANOPARTICLES

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ABSTRACT

The adsorption process by metal oxide nanoparticles has been investigated an effective agent for removing organic and inorganic contaminants from water and wastewater. In this study, iron oxide nanoparticles were synthesized in the presence of *moringa oliefera* pods as adsorbent for lead, copper and cadmium ions adsorption. *Moringa oliefera* pods biochar with Fe_3O_4 particles precipitated on the surface of biochar was synthetized by co-precipitation method. Batch adsorption method was used, and heavy metal ions percentage recovery was measured using ICP-OES. Effect of various parameters such as contact time, pH, metal concentration and adsorbent dosage was determined on the removal efficiency. The maximum adsorption capacities of Pb^{2+}, Cd^{2+}, and Cu^{2+} by MMC were 31.46 $mg \cdot g^{-1}$, 29.05 $mg \cdot g^{-1}$ and 27.66 $mg \cdot g^{-1}$, respectively. The Langmuir and Freundlich isotherm equations were used to analyze the equilibrium isotherm data. The adsorption process fit the second-order kinetics well in all cases, and the Langmuir isotherm equation fit the experimental data well.

Keywords: *Moringa Oleifera*, iron oxide nanoparticles, co-precipitation, adsorption

INTRODUCTION

Water is an essential element for the sustainability and development of life on Earth. An average person requires around 50 liters of water per day, to fulfil their biological needs and domestic activities (Howard, & Bartman, 2003). To guarantee access to safe drinking water is a political concern at national, provincial and local

levels. It ensures the health safety of the population, given that, the lack of it promotes the proliferation of diseases (World Health Organization [WHO], 2017). Children and young people are the most vulnerable to get water-related diseases like diarrhea, trachoma, schistosomiasis and other diseases, preventable diseases (Howard, & Bartman, 2003) which due to the absence of drinking water and suitable sanitation, nowadays are the cause of 2 million to 5 million deaths per year (World Health Organization [WHO], & United Nations Children's Fund [UNICEF], 2000). The Earth is mostly constituted by water, covering almost 70 % of it. However, 96.5 % of the hydrosphere is saline water from the oceans and just 2.5 percent is freshwater which, around 68 % of it is enclosed in ice caps, glaciers and snow (Shiklomanov, 2003, pp 13-23; Mushtaq, Singh, Bhat, Dervash, & Hameed, 2020, pp 27-50).

Freshwater complies an important role in preserving life, how it is used and dispose of is an environmental issue of international concern (Gleick, 2003). Especially, due to the high level of water's vulnerability to contamination (Mushtaq, et al., 2020, pp 27-50), which can be polluted by different sources as microbial, chemical, physical or biotic factors (WHO, 2017). The main reason for water pollution is due to anthropogenic activities, and the rapid increase in human population makes the situation even worse (Gleick, 2003). Overcrowded areas, industrial activities, discharge of fields, production and use of plastic, chemicals, debris, etc., are just a few examples of the damage to the planet's sources of water (Mushtaq, et al., 2020, pp 27-50).

Several water-treatment technologies are now being combined around the world, taking into account various elements such as population, implementation and maintenance costs, and community behaviour to assure the system's long-term success (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2009). Depending on the scope of the system, it can be applied at home or for a whole community. For household water treatment, there are three main methods: boiling the water, slow sand filter, and domestic chlorination. While, for a community, there are other options like: storage and sedimentation, up-flow roughing filter, complete water treatment plants and chlorination in piped water-supply systems (Trösch, 2009, pp 394–397). Despite the efforts to provide access to drinking water and sanitation to all nations, new threats are found during the process, such as economic troubles, lack of workforce or human resources, minimum political interest, absence of access roads, etc (WHO & UNICEF, 2000). Thus, there are numerous communities around the world without access to drinking water waiting for a solution to their hard reality (Howard, & Bartman, 2003). Scientific research suggests the possibility of using natural technologies, such as: soil filters, treatment wetlands, aerobic and anaerobic treatments, as the first solution to this matter (Rozkošný, Kriška, Šálek, Bodík, & Istenič, 2014). However, the search for natural, replicable and accessible options is still being pursuit.

With the aforementioned in mind, the objective of this study was to develop an efficient magnetic compound adsorbent from *Moringa Oilefera* pod readily available. The magnetic compound adsorbent will then be utilized for the removal of inorganic (Cd^{2+}, Pb^{2+} & Cu^{2+}) cationic pollutants, and the experimental data described using kinetic and adsorption isotherm models.

EXPERIMENTAL

Material and Methods

Collection and Preparation of *Moringa Oleifera* Pods

Moringa oleifera pods were collected from trees in Limpopo farm near Polokwane. Soon after collection, pods were washed thoroughly with doubly distilled deionized water to remove water soluble impurities and oven dried at 105°C for 24 hours. The washed and dried material was pulverized (by mortar and pestle) and sieved to different mesh sizes. The sieved material was rewashed thoroughly with doubly distilled deionized water to remove the fine particles and dried at 105°C for 4 hours. The material was treated with 0.1M nitric acid and methanol for 4 hours to remove inorganic and

organic matter from the sorbent surface and dried in an electric furnace. The treated and untreated materials were then placed in a desiccator to be used as sorbents.

Batch biosorption experiments were conducted to investigate the influence of physiochemical parameters such as contact time, metal ion concentration, adsorbent dosage, and temperature on heavy metals ion adsorption. Batch experiments were performed for different metal concentrations (20 - 100 mg. L^{-1}), temperature (20 - 60°C), adsorbent dose (0.25 - 1.0 g) and contact time (0 - 60 min). After prescribed contact time, the solution was filtrated using filter syringe and the concentration of metal in the filtrate was measured using atomic adsorption spectroscopy.

Preparation of the iron oxide magnetic nanoparticles, biochar, and composite

The Fe_3O_4 magnetic nanoparticles (MNP) was prepared from a 400mL solution of $FeCl_3$ (7.8 g, 28 mmol) and $FeSO_4$ (3.9 g, 14 mmol) at room temperature using the chemical co-precipitation method (Oliveira, et al., 2003). The solution was continuously stirred with an overhead stirrer while 1.0M NaOH solution was added drop-wise to precipitate the MNP. The MNP was magnetically separated, washed with water and then ethanol before drying. The mass of MNP after drying was noted.

The pulverized *moringa* pods (PMP) was separately charred in a crucible at 250°C for 4 hours to obtain the *moringa* biochar (MBC). The biomass was first dried at 110°C for 1 hour before increasing the temperature at a rate of 5°C /min until 250°C which was maintained for 4 hours. The PBC was then cooled, ground, sieved through a 230 mm mesh size sieve. This was followed by washing until the filtrate was colourless indicating no leaching of residual Fe or carbon. The MBC was again dried at 105°C for 2 hours, cooled, weighed noted, and stored.

The MBC-MNP combo (MMC) was prepared by calcining the treated *moringa* pods (MOP) and MNP. The MNP was prepared by chemical co-precipitation in the presence of the treated MOP and subsequently calcining at 250°C. Typically, the MOP was suspended in a 400 mL solution of $FeCl_3$ (7.8 g) and $FeSO_4$ (3.9 g) and stirred thoroughly to allow for wetness. A solution of 1.0M NaOH solution was added drop-wise to raise suspension pH to 10 and precipitate the MNP on the MOP surface. The solution was further stirred for 30 min before separation by centrifugation at 2500 rpm for 4 min. followed by filling of the residue into a crucible for the calcining process. The crucible was heated at 110°C for 1 hour before raising the temperature at a rate of 5°C/min until 250°C which stood for 4 h. After the calcining process, the MMC combo was cooled and washed with water until the filtrate was colourless indicating no leaching of organic matter or iron. The MMC was subsequently dried at 105°C for 2 hours and stored.

Data Management

Adsorption capacity (mg. g^{-1}) at equilibrium for adsorption of analyte were determined by equation 1.

$$q_e = \frac{(C_0 - C_e)}{M} V \qquad 1$$

where C_o and C_e are the initial and final pollutant concentrations (mg. L^{-1}), respectively, while M (mg) and V (mL) are the MMC mass and solution volume, respectively.

Adsorption Isotherm of MMC

Langmuir and Freundlich adsorption isotherm models were used to depict the equilibrium between adsorbed Pb^{2+}, Cd^{2+} and Cu^{2+} on MMC (q_e) and ions concentration in solution (C_e) at constant temperature (30 °C).

Kinetic Study of MMC

The pseudo-first order and pseudo-second order kinetic models were used to describe the adsorption process.

Thermodynamic Parameters

Thermodynamic parameters such as *Gibbs free energy* (ΔG), *enthalpy* (ΔH) and *entropy* (ΔS) for the adsorption of cations on PILC are calculated using the following equations (Airoldi, Machado, & Lazarin,

2006; Guerra, Lemos, Airoldi, & Angelica, 2006):

$$\Delta G = -RT\ InK_L \qquad 2$$

where K_L is the equilibrium constant obtained from Langmuir model, T the absolute temperature (K) and the universal gas constant R=8.314×10^{-3} kJK^{-1}mol^{-1}. The relationship between K and thermodynamic parameters of ΔH and ΔS can be described by the Van't Hoff correlation in the following equation (Celik, & Ozdemir, 2018; Yildiz, Erol, Aktas, & Alimli, 2004):

$$InK = \frac{\Delta S}{R} - \frac{\Delta H}{RT} \qquad 3$$

The thermodynamic study was made at three different levels of temperatures which were 25, 40 and 70 °C.

RESULTS

Fourier Transform Infrared Spectroscopy (FTIR)

The main functional groups present in the *M. oleifera* pods were characterized by infrared material analysis. The FTIR, one can confirm the potential applicability of adsorption of different pollutants on *M. oleifera* with sufficient and satisfactory removal efficiency. As shown in Figure 1(a-b), the FTIR spectroscopic analysis indicated broad band at 3326 cm^{-1}, representing bonded – OH groups. The band observed at 2917–2849 cm^{-1} was assigned to the aliphatic C–H group. The peak around 1623 cm^{-1} corresponds to C=O stretch. The peak observed at 1541 cm^{-1} corresponds to the secondary amine group, while the peak at 1374 cm^{-1} corresponds to the symmetric bending of CH_3; the one observed at 1314 cm^{-1} corresponds to the C–H bending. Also, the peak observed at 1242 cm^{-1} corresponds to the $–SO_3$ stretching, at 1029 cm^{-1} corresponds to C=O bonds of ether, ester or phenol, at 668 cm^{-1} corresponds to –CN stretching, while the peak observed at 564 cm^{-1} corresponds to S–O. On the other hand, typical functional groups for iron oxide are depicted by absorption band at 3660 cm^{-1} that corresponds to the hydroxyl functional group and a band obtained at 531 cm^{-1} is characteristic of $M_{tetrahedral}$ resonance with O. This peak also relates to Fe-O group. These results are in confirmation with the study by: (Amuanyena, Kandawa-Schulz, & Kwaambwa, 2019).

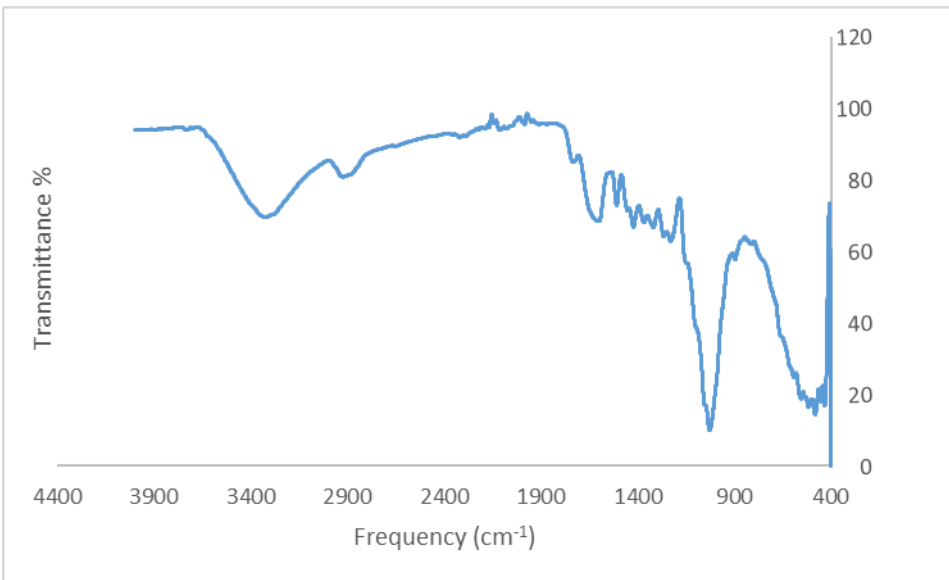

Figure 1a: FT-IR spectrum of *moringa oleifera* pods.

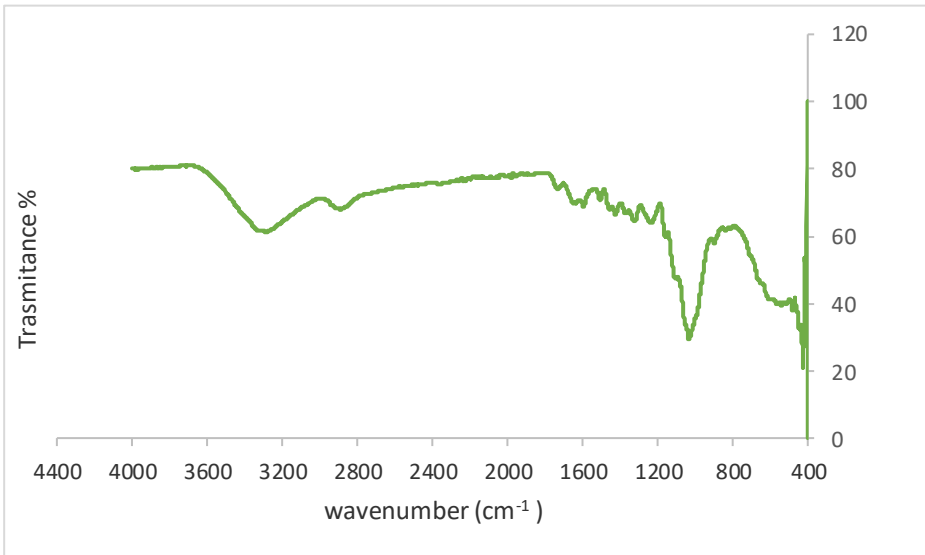

Figure 1b: FT-IR spectrum of magnetic *moringa oleifera* pods.

Scanning electron microscope (SEM)

The SEM images (Figure 2a-b) were evaluated to study the surface morphology of the adsorbents before adsorption of the cations. The SEM images of the *M. oliefera* pods biomass were foamy and fibre-like in nature with no particular shape as reported elsewhere (Tavengwa, Cukrowska, & Chimuka, 2016). However, after the thermal treatment (250°C) the surface morphology revealed macropores and irregular trough-like patterns. The structure appeared frail and the cell morphology of plant biochar was absent. The micrographs of *moringa* pods (Figure 2(a)) reveal mesoporous structures with different pore sizes. These surface characteristics would result in high metal binding due to available binding cavities for the metal ions (Araujo, et al., 2010; Maina, Obuseng, & Nareetsile, 2016). The porosity for the magnetic *moringa* composite has improved compared to the modified *moringa* pods. This may therefore explain the difference in the adsorption capacity of metal ions using these adsorbents. As also shown, the magnetite composite seems to have agglomerated and this could be attributed to strong bonding of nanoparticles, magnetic dipoles as well as Van der Wall forces (Ehrampoush, Miria, Salmani, & Mahvi, 2015; Rajput, Pittman, & Mohan, 2016).

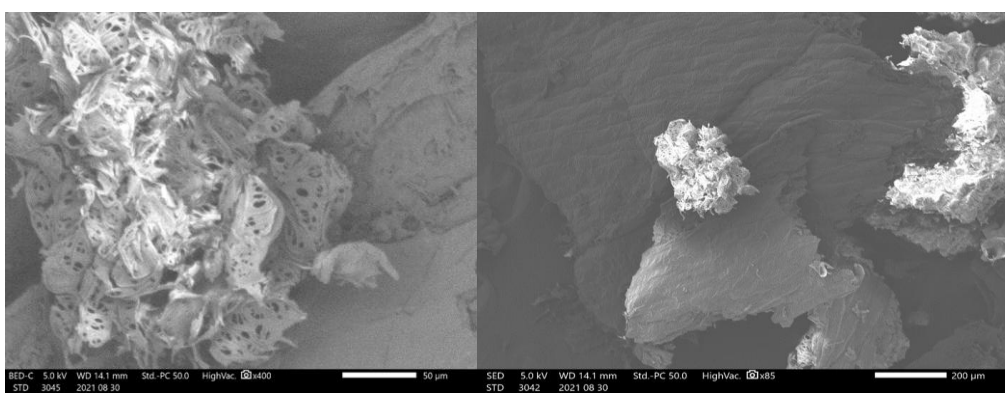

Figure 2: SEM images: (a). MOP before adsorption, (b). MMC before adsorption

Thermogravimetric analysis (TGA)

Thermal stability of MMC was studied when MMC was heated from 20, 50˚C to 80˚C as shown in Figure 3. The different thermal decomposition stages in terms of percentage weight loss and their respective derivatives weight loss percentage per ˚C were obtained by: (Araujo, et al., 2010). The first stage between 20˚C to 100˚C is associated with water loss. The second stage ranging from 100˚C to 350˚C could be due to loss of organic matter that might include proteins amino acid residues with various functional groups and other low molecular weight compounds. The third stage between 350˚C to 780˚C might be from compounds with higher boiling point. At the end of the decomposition stage (780˚C), the total residue was therefore attained.

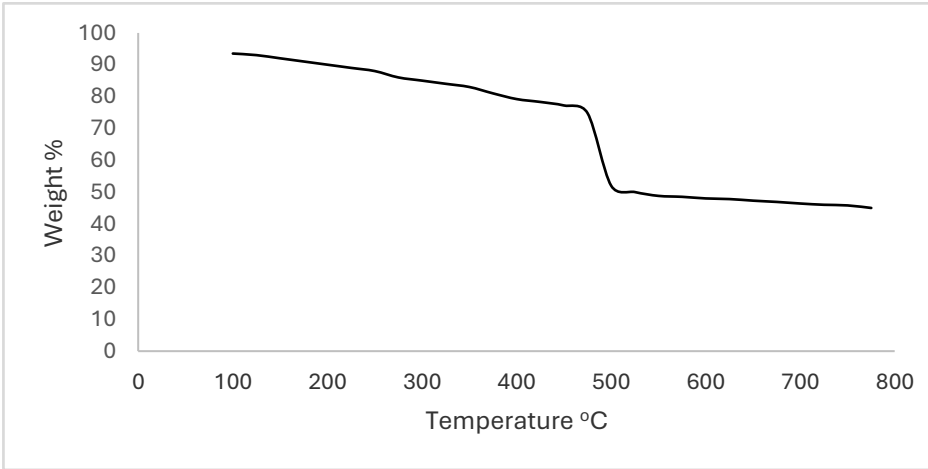

Figure 3: TGA curve for MMC

Effect of contact time

The effect of contact time is shown in Figure 4, indicates the biosorption capacity of MMC for heavy metal ions and it was investigated for various initial concentration 20 - 100 mg. L^{-1} at temperature 25°C, with a fixed adsorbent dose 0.25 - 1 g at interval of 10 min. From the obtained results, it is observed that the percentage of removal of heavy metal ions increases sharply with contact time in the first 10 min. This is due to the presence of large number of vacant sites. As the time proceeds, the removal decreases due to the accumulation of metal ions on the vacant sites until it approaches equilibrium. A study by Maina, et al. (2016) explained further that increase in percentage recoveries with increase in adsorbent dosage is observed until an optimal adsorption level is attained after which the percentage recoveries are reduced due to the decline in vacant active sites on the surface of the adsorbent. Therefore, further increase in contact time did not enhance the biosorption removal, and the optimum contact time within 60 min for lead, copper and cadmium as shown in Figure 4, after that a maximum removal is attained.

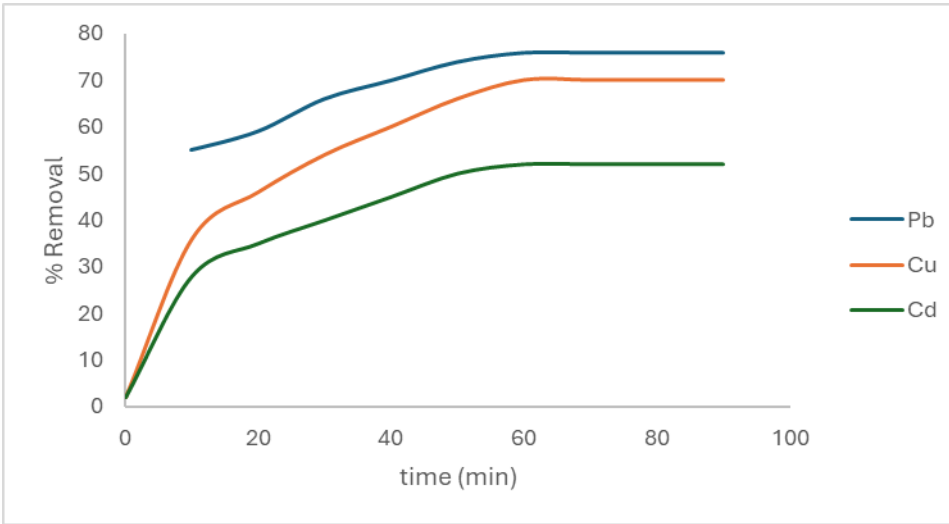

Figure 4: Effects of contact time

Effect of pH

The pH of solution has been identified as the most important variable affecting metal adsorption onto adsorbent. This is partly because hydrogen ions themselves are strongly competing with adsorbate. The removal of Pb^{2+} as a function of hydrogen ion concentration was examined at pH 2 - 9. The removal efficiency was found to be highly dependent on hydrogen ion concentration of solution. The effect of pH on adsorption efficiency is shown in Figure 5. The cadmium ions are usually soluble in acidic pH and the maximum removal of cadmium was obtained in the pH of 4.

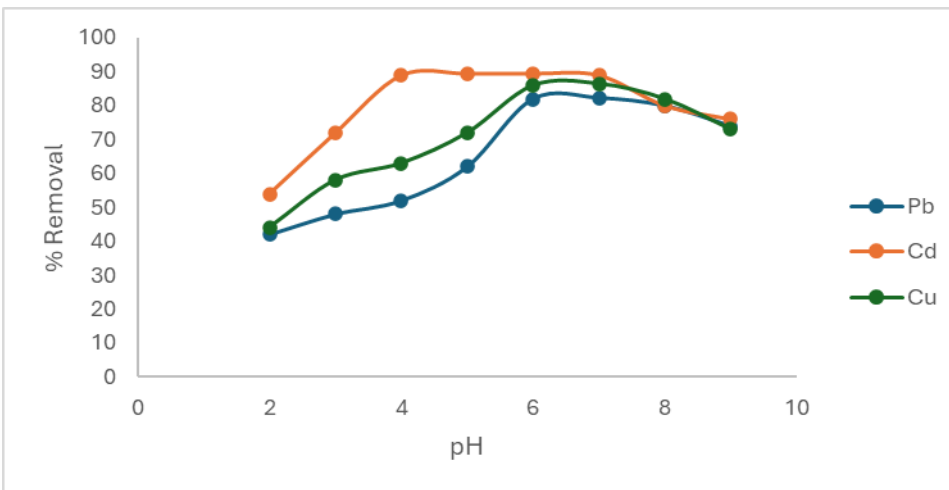

Figure 5: Effects of pH

Effect of biosorbent dose

The adsorption process is affected by adsorbent dose of the aqueous solution. It is clear that the biosorbent dosage parameter plays an important role on the adsorption process. To achieve maximum biosorption capacity, the optimum dosage of MMC must be determined. In such, different amounts of MMC have been used, varying from 0.25 to 1 g of solution with 20 - 100 mg. L^{-1} concentration of heavy metals with temperature kept at 25°C. The effect of adsorbent dose on heavy metal removal is shown in Figure 6. Obviously, the adsorption increased as the sorbent dose of MMC increased. It is elaborated that maximum biosorption attained at biosorbent dosage 1 g is 82, 90 and 92% for Pb^{2+}, Cu^{2+} & Cd^{2+}, respectively, as shown in Figure 6.

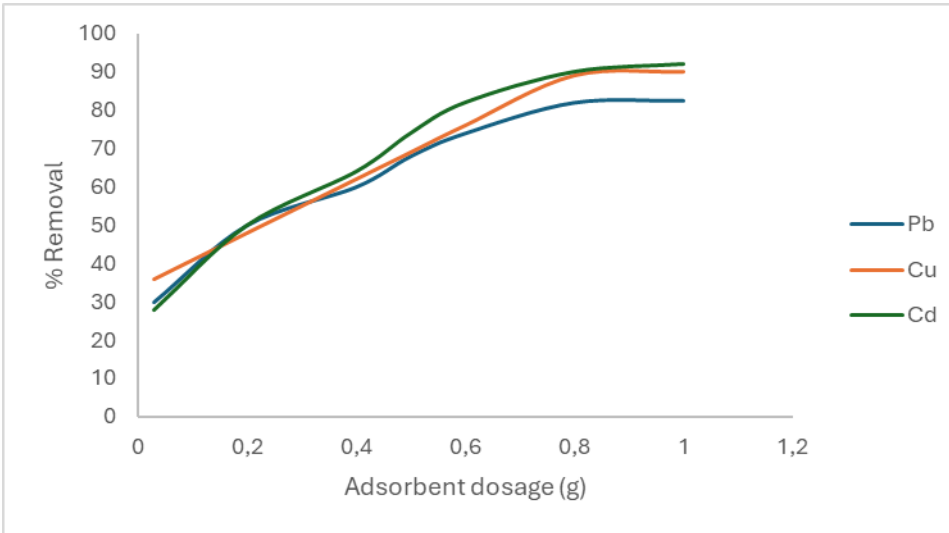

Figure 6: Effect of adsorbent dosage

Effect of temperature

To study the effect of temperature on the amount of uptake of metal ions, the adsorption process was investigated at three different temperatures 25, 40 and 70°C with concentrations of 25 - 100 mg. L^{-1} and constant adsorbent doses 0.25 - 1.00 g. According to Figure 7 the amount of adsorption capacity decreases with the increase of temperature for copper and cadmium. Also, reveals that the lead ions' removal occurs in an exothermic way, once the temperature increases, there is a tendency of reducing lead removal percentage. Thus, the optimal temperature for the removal is at 25°C. Regarding the exothermic characteristic of biosorption, where the process is favoured at low temperatures, (Nordine, et al., 2014), in their work on lead biosorption by pine and sawdust, concluded that the increase in temperature may be causing the destruction and solubilisation of the adsorption sites, thus justifying the lowest percentage of removal obtained by raising the temperature.

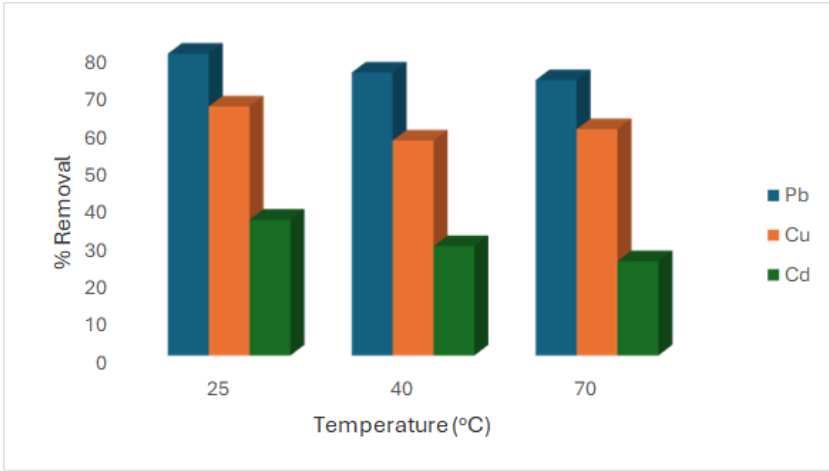

Figure 7: Effect of temperature

Initial metal concentration

As the initial concentration for metal ions increases, the removal percentage decreases for a fixed adsorbent dose and contact time. This behaviour can be explained due to limited active site on the adsorbent surface. The results as depicted in Figure 8, show one example for copper, lead and cadmium ions removal at different concentration and at 25°C. This figure reveals that the amount of metal ions adsorbed per unit mass of adsorbent increase with increasing in concentration from 20 to 100 mg. L^{-1}. At higher concentration, the numbers of metal ions are relatively higher than the available sites, hence, decreasing the removal percentage. Whereas, increasing the biosorbent dose yields to more active sites, which enhance the metal ions uptake. However, further increase in mass for certain metal ions did not bring any further improvement in the removal percentage. With each increasing metal ion concentration, there was an increase in the amount of metal ion adsorbed due to increasing driving force of the metal ions toward the active sites on the adsorbents (Obuseng, Nareetsile, & Kwaambwa, 2012), but the percentage of ions remaining in the solution also increased because of the increscent initial concentration. It indicated a decrease in the active sites on the sorbent as more metal ions were adsorbed.

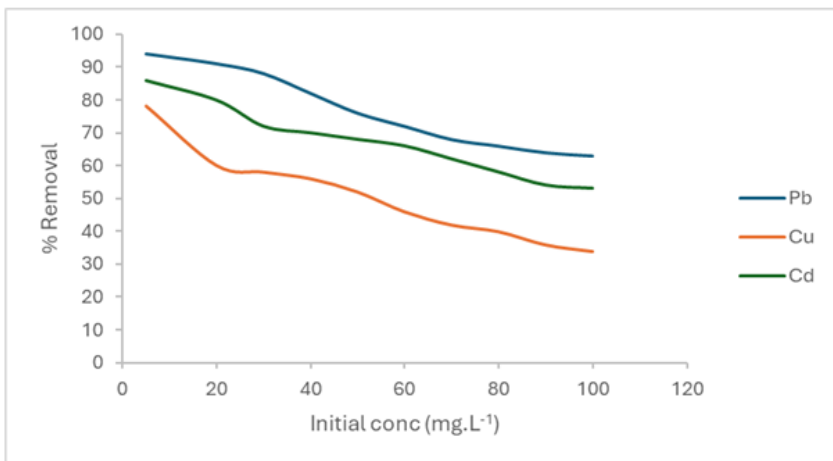

Figure 8: Effect of the initial concentration

Kinetic study

The kinetic studies and modelling of the experimental data are presented in Figure 9 and certain parameters are shown in Table 1. From the correlation coefficient obtained as presented in Table 1 for the pseudo-first-order and pseudo-second order models, it is verified that both models fit well to the experimental data. The pseudo-second-order model proposed by (Ho, Wase, & Forster, 1996) assumes that the process occurs by chemical adsorption involving the participation of valence forces or electron exchange between the metal and the biosorbent, while the pseudo-first-order model assumes the occurrence of the adsorption by physisorption.

In this study, the highest correlation coefficient was obtained for the kinetic model of pseudo-second-order, which is the model that best adapts to the experimental data. A preliminary comparison related to adsorption velocity (q_e) between the calculated and experimental values can be performed to prove the best fit, since the values calculated by the kinetic model of pseudo-second-order are closer to those obtained experimentally.

Table 1. Obtained parameters of kinetics models for adsorption on MMC

Ion	Pseudo-first-order				Pseudo-second-order			
	k_1	$q_{e.cal}$	$q_{e.exp}$	R^2	k_2	$q_{e.cal}$	$q_{e.exp}$	R^2
Pb	1.01	38.61	39.10	0.9960	8.53	39.18	39.10	0.9995
Cu	0.58	37.07	38.41	0.9716	2.98	38.73	38.41	0.9961
Cd	1.08	37.98	38.79	0.9931	9.27	38.74	38.79	0.9989

The biosorption rate constant obtained by the pseudo-2nd order has a higher sorption rate for Cd^{2+}, while the Cu^{2+} has lower rate. The values for the rate constants ranged from 2.98 to 9.27 mg. g^{-1} min^{-1}.

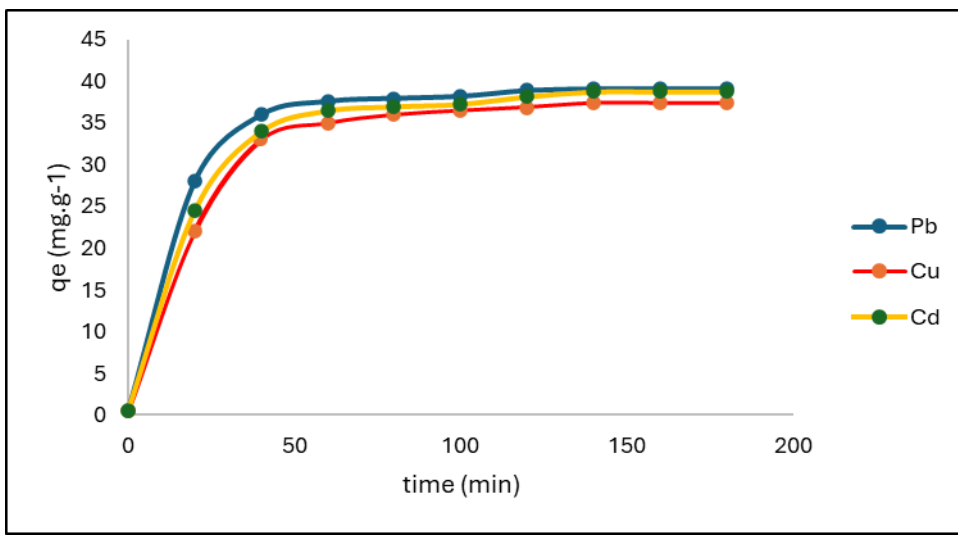

Figure 9: Pseudo-second-order kinetics model for experimental data.

Adsorption thermodynamics

The values of ΔH° and ΔS° could be calculated from the slope of the curve ln K_d versus 1/T, as shown in Figure 10. The thermodynamic parameters obtained from the lead biosorption process are shown in Table 2.

According to Table 2, thermodynamic parameters (ΔG°, ΔH° and ΔS°) of MMC evaluated presented negative values. According to: (Abdeen, Mohammad, & Mahmoud, 2015), negative ΔG° values obtained in respect of studied temperatures show spontaneous and viability natures of biosorption process for lead, copper and cadmium on MMC. Negative ΔH° values confirm that the process has exothermic nature. Kelleher, et al. explain that negative ΔS° values are associated with an increase in the degree of organization of the system, associated with the adsorbate particles' accommodation in more ordered layers on the surface of the adsorbent. It further indicates that there is no dissociation or increased mobility of the particles on the surface of the adsorbent (Kelleher, O'Callaghan, Leahy, O'Dwyer, & Leahy, 2002).

Table 2. Thermodynamics parameters for Pb, Cu & Cd adsorption by MMC

Ion	ΔG° (kJ mol^{-1})					
	298K	308K	318K	R^2	ΔH°(kJ mol^{-1})	ΔS° (J mol^{-1} K^{-1})
Pb	-10.01	-9.69	-9.20	0.9966	-22.16	-40.56
Cu	-12.60	-10.6	-9.89	0.9901	-53.68	-137.5
Cd	-8.32	-8.31	-8.31	0.9991	-8.78	-1.52

In this study, the calculated entropy is negative, according to: (Acharya, Sahu, Mohanty, & Meikap, 2009), negative ΔS° values suggest the probability of a favourable sorption.

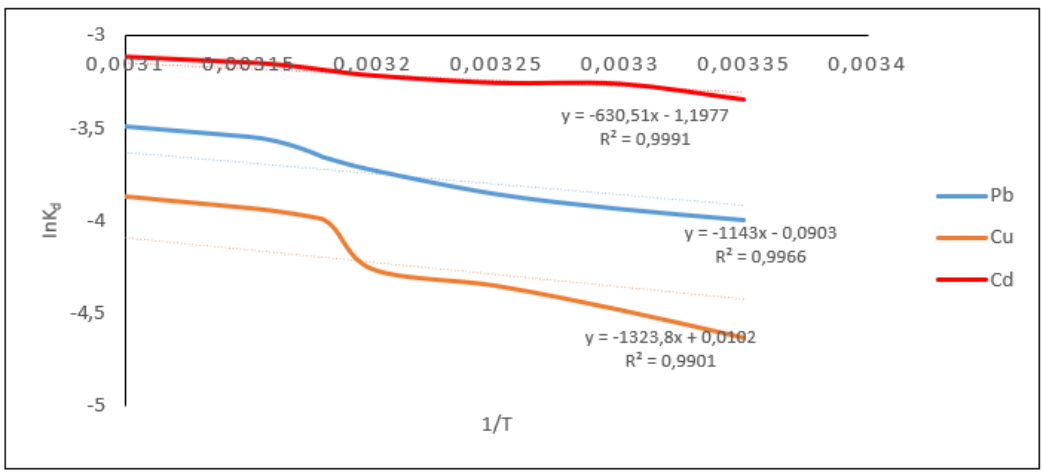

Figure 10: Graph of ln K versus 1/T for the estimation of thermodynamic parameters of biosorption of Pb, Cu & Cd by MMC

Adsorption isotherms

For selecting the optimum operating conditions, the kinetics of metal ions removal was carried out with the help of kinetic models (including pseudo-first order and pseudo-second order models) to investigate the mechanism of sorption and rate controlling steps. The models are fitted to experimental data by nonlinear regression analysis, using coefficient of determination. The preliminary study developed to analyse biosorbents indicated, as optimal conditions for having maximum removal, the use of pH 5.5, contact time 60 min, biosorbent dosage 0.5 g, 50 mL^{-1} and 25°C temperature. Table 3 shows the obtained constants of sorption isotherms for magnetic moringa biosorbents in accordance with the Langmuir and Freundlich models.

Table 3. Langmuir model and Freundlich model parameters.

	Langmuir Model			Freundlich Model		
Ions	**q_{max}**	**b**	**R^2**	**k_F**	**n**	**R^2**
Pb^{2+}	31.46	0.21	0.9960	4.09	1.26	0.9863
Cd^{2+}	29.05	0.33	0.9952	1.52	0.39	0.9913
Cu^{2+}	27.66	0.13	0.9968	4.29	1.69	0.9896

From the correlation coefficients (R^2) shown in Table 3, it can be concluded that the Freundlich model does not fit the experimental data, while the model of Langmuir has a good fit. The MMC FTIR spectra showed that metal ions biosorption by moringa seeds occurs, probably, from the chemisorption, in which the chemical interaction between the metal present in the fluid phase and biosorbent was part of the process, resulting, thus, in the transference of electrons equivalent to the formation of chemical bonds between the adsorbate and a solid surface.

CONCLUSION

Various characterization techniques namely, Fourier transform infrared spectroscopy, thermal gravimetric analysis and scanning electron microscope were applied to assess diverse functional groups responsible for adsorption and morphology. The Fourier transform infrared spectroscopy confirmed various functional groups such as amine/amide, carbonyl, hydroxyl, carboxylic and iron oxide on modified magnetic iron oxide nanoparticles that could be responsible for selective recovery of heavy metal ions. Scanning electron microscope depicted porous morphology with various pore sizes that might be responsible for retention of precious metal ions. The optimal conditions for recovery of the heavy metal ions obtained from the study were: pH 6; 60 minutes' agitation time. Furthermore, the experimental data fit the Langmuir and Freundlich models, indicating that the adsorption sites were unequal and non-specific. The findings of the kinetic model fitting revealed that heavy metal ions diffusion and chemisorption processes were limiting the adsorption process. The adsorption process fit the second-order kinetics well in all cases, and the Langmuir isotherm equation fit the experimental data well. The obtained results of this investigation indicated that the synthesized adsorbent was abler to remove heavy metals ions.

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REZULTATI PRIMJENE *ADDENBROOKE´S* REVIDIRANOG TESTA KOGNITIVNE PROCJENE: KOMPARACIJA DVA PRIKAZA SLUČAJA

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APSTRAKT

ACE-R je široko prihvaćen instrument u kliničkoj praksi čijim revidiranjem su prevaziđene izvjesne slabosti. Cilj ovog rada bio je da se prikažu rezultati istraživanja testa ACE-R, te da se analiziraju i uporede rezultati dobijeni u radu sa zdravom ispitanicom i ispitanicom sa kliničkom dijagnozom. Ispitanice su sličnih godina i sličnih karakteristika. Iz kliničke populacije izabrana je ispitanica sa dijagnozom depresije nakon moždanog udara, što predstavlja i najčešću komplikaciju istog. Rezultati dobijeni u ovom radu su djelimično potvrdili rezultate prethodih istraživanja. Primjena navedenog testa pokazala je da se dvije ispitanice razlikuju u pogledu mjerenih sposobnosti: ispitanica sa dijagnozom depresije produkuje teškoće rekognicije zadatog materijala, a verbalna fluentnost i vizuospacijalne sposobnosti su snižene u odnosu na zdravu ispitanicu.

Ključne riječi: ACE-R, moždani udar, depresija, zdrava ispitanica, ispitanica sa dijagnozom.

UVOD

Addenbrooke revidirana skala za procjenu kognicije (ACE-R) je test koji je prvobitno dizajniran kao kraći test namijenjen detekciji ranog stadijuma demencije (Salak-Đokić, 2018). Originalna verzija testa (Mioshi i sar., 2006.) je prevedena i adaptirana u skladu sa kulturološkim osobinama naše populacije. Test uključuje MMSE, obuhvata pet domena od kojih se svaki odnosi na specifičnu kognitivnu funkciju: 1) pažnju i orijentaciju (18 poena), pamćenje (26 poena), fluentnost (14 poena), govor i jezik (26 poena), vizuospacijalne sposobnosti (16). Maksimalan skor je 100 poena (uključuje MMSE skor 30). Viši skor reflektuje bolje kognitivno funkcionisanje. Vrijeme zadavanja je 15 do 20 minuta.

Za razliku od drugih testova (MMSE, MoCA), ACE-R pruža ispitivaču kratki kognitivni pregled sastavljen od više komponenti, budući da pruža specifične

rezultate za različite kognitivne domene. To kliničarima, uz rezultate ostalih neuropsiholoških instrumenata pruža adekvatno usmjeravanje i mogućnost personalizovanog pristupa svakom pacijentu.

Adenbrookeovo kognitivno testiranje ima statistički značajnu tačku koja sa sigurnošću detektuje blagi kognitivni poremećaj, što ga čini relevantnim među različitim populacijama. Posebna važnost ovog testa jeste, mogućnost razdvajanja pacijenata na one sa amnestičkim i one sa ne-amnestičkim blagim kognitivnim poremećajem. Kao i sve podkategorije, ona koja ispituje pamćenje se boduje posebno, te je prelomna vrijednost 17 bodova. Zavisno od rezultata na ostatku ACE-R testa, te rezultatima pojedinačnih kategorija, može se otkriti je li pamćenje jedina ili jedna od više domena u kojima pacijent ima deficit.

Suptest Orijentacija

Ovo je dio skale koji obuhvata 4 zadatka koja su istovremeno dio iz MMSE: Orijentacija vremenska i prostorna; neposredno pamćenje tri riječi; serijsko oduzimanje ili pažnja i koncentracija.

Suptest Pamćenje

Obuhvata nekoliko suptestova namjenjenih ispitivanju odloženog, anterogradnog i retrogradnog verbalnog pamćenja. Odloženo pamćenje se odnosi na prisjećanje tri riječi prezentovane tokom faze nepsrednog učenja, odnosno prije distrakcije serijskim oduzimanjem, takođe dio iz MMSE (3 poena); anterogradno sjećanje - od ispitanika se zahtjeva da u tri pokušaja, nakon ispitivača, reprodukuje verbalno prezentovano ime, prezime, tačnu adresu, grad i državu imaginarne osobe, pri čemu se ocjenjuje samo poslednji pokušaj (7 poena). Ovaj zadatak je adaptiran kako bi prikazivao srpske zadatke, a pritom ostavio svoju originalnu verziju. Nakon perioda odlaganja u kojem se izvršavaju drugi zadaci, od ispitanika se zahtjeva da ponovi informacije iz prve faze (5 poena), a onda i putem višestrukog ponuđenog izbora (7 poena). Svako pitanje nosi 1 poen (makismalno 4 poena). Ukupan broj poena za cijeli suptest iznosi 26.

Suptest Fluentnost

On, u originalnoj verziji, kao samostalan test, je namjenjen mjerenju fonemske i kategorijalne fluentnosti. Za razliku od samostalnog testa, u okviru ACE-R-a test fonemske fluentnosti se sastoji od nabrajanja što više riječi koje počinju na slovo „S". Isto tako, drugi dio ovog subtesta u okviru ACR-R-a mjeri kategorijalnu fluentnost, pri čemu je zadatak nabrajanje što više životinja. Maksimalan broj poena na cijeloj supskali Fluentnost iznosi 14 poena.

Suptest Govor i jezik

Namjenjen je ispitivanju različitih aspekata govorno - jezičkih funkcija i uključuje pet grupa zadataka: razumijevanje pisanog naloga (1 poen) i usmeno prezentovanog trostrukog naloga (3 poena); pisanje rečenice po sopstvenom izboru (1 poen); ponavaljanje 4 riječi različite artikulacione težine (2 poena), ponavljanje 2 fraze različite složenosti od kojih je poslednja modifikovana u izraz "Nema ali i niti ako" (2 poena); imenovanje 2 jednostavna prezentovana objekta (2 poena); imenovanje crteža 10 objekata različite težine i konvencionalnosti (10 poena) i nakon toga identifikovanje 4 objekata sa prethodno prikazanih crteža prema kraćoj definiciji ("pokažite mi šta Vas asocira na torbare?") (4 poena); Čitanje 5 riječi (1 poen). Maksimalan broj poena na ovoj supskali iznosi 26.

Suptest Vizuoprostorne sposobnosti

Suptest namjenjen procjeni vizuelnih i vizuokonstruktivnih kapaciteta ispitanika, obuhvata 5 zadataka: precrtavanje ukrštenih petouglova (zadatak iz MMSE) (1 poen), precrtavanje trodimenzionalnog objekta - kocke (2 poena), test crtanja sata (5 poena), perceptivne sposobnosti - prebrojavanje tačaka (4 poena) i prepoznavanje 4 slova (4 poena).

Moždani udar jeste neurološki poremećaj naglog nastanka uzrokovan zbog poremećaja cirkulacije u mozgu (Cerovec, 2020). Poremećaj cirkulacije mogu uzrokovati začepljenje arterija ugruškom koji onemogućava pravilan protok krvne žile zbog

kojeg dolazi do krvarenja u okolno moždano tkivo. Posljedično tome dolazi do nedostatka prehrane i opskrbljivanja određenih dijelova u mozgu kiseonikom i postepenog odumiranja moždanih ćelija u zahvaćenom dijelu mozga. Osobe koje su preživjele moždani udar često ostanu zavisne od pomoći drugih ljudi prilikom obavljanja svakodnevnih aktivnosti što kod njih uzrokuje osjećaj frustracije i ljutnje koji su u većini slučajeva odražavaju na njihove najbliže članove porodice. Kao prateća stanja moždanog udara kod nekih osoba dolazi do osjećaja bespomoćnosti, beznadežnosti i krivice za nastalo stanje i situaciju i kojoj se nalaze. Ovakve osobe se povlače u sebe, odbijaju pomoć i njihovo se psihičko stanje svakodnevno pogoršava, drugim riječima one postepeno padaju u takozvanu depresiju poslije moždanog udara (Cerovec, 2020).

Poslije moždanog udara, pojedini autori dijele neuropsihološke posljedice na kognitivne, nekognitivne i specifična stanja.

Kognitivna oštećenja spadaju u grupu demencija. Nekognitivni poremećaji se odnose na depresiju, anksiozni poremećaj, PTSP i psihotična stanja. Nespecifična stanja uključuju: emocionalno nestabilno stanje, apatiju, vaskularnu depresiju i sindrom nesposobnosti izvršnog funkcionisanja (Mihaljević-Peleš, 2022).

Depresija nakon moždanog najpoznatiji je psihički poremećaj. U ovom momentu u klasifikaciji ne postoji posebna klasifikacija ovakve vrste depresije, već se koristi dijagnoza u DSM 5 – depresija zbog drugih medicinskih razloga ili u MKB 10 – organski uslovljena depresija F06.3. Ona je povezana je sa znatno lošim ishodom, a neke studije pokazuju i negativan uticaj na stopu preživljavanja (Mihaljević-Peleš, 2022). Uopšteno, depresija nakon moždanog udara se javlja u rasponu od 25 % do 35 % kod osoba koje su preživjele moždani udar, s nešto većom pojavom u prvoj godini i postepenim smanjivanjem iza prve godine.

Prema jednom istraživanju na 100 bolesnika s moždanim udarom koji su praćeni 18 mjeseci depresivni poremećaj se javlja kod 46% bolesnika nakon dva mjeseca i tek u 12% ispitanika se depresija javila nakon 12 mjeseci nakon moždanog udara (Mihaljević-Peleš, 2022). Prevalencija depresije nakon moždanog udara kreće se od 20 do više od 70% u zavisnosti od ispitivane populaciji, kao i na osnovu mjernih instrumenata. Prema jednom istraživanju u populaciji se depresija nakon moždanog udara javlja u oko 31.8% slučajeva, u populaciji akutno hospitalizovanih oko 47% dok u populaciji bolesnika na rehabilitaciji nakon moždanog udara depresija se javlja i do 72% te populacije.

Takođe pojava depresije nakon moždanog udara zavisi i od lokalizacije moždanog udara. U jednom istraživanju do 82% bolesnika s udarom u području Arterije cerebri medije, dakle područje frontalnog, parijetalnog i temopralnog režnja. Manje od 10% bolesnika s moždanim udarom u području stražnje cirukulacije je imalo depresiju. Nakon godine dana do 62% bolesnika s moždanim udarom u području prednje cirkulacije je imalo depresiju dok se depresija nije zabilježila godinu dana nakon moždanog udara u području stražnje cirkulacije (Mihaljević-Peleš, 2022).

U liječenju depresije nakon moždanog udara treba poduzeti mjere koje dovode do rizičnih faktora. Naime liječenje depresije nakon moždanog udara je komplikovanije nego liječenje samostalne depresije prvenstveno jer je ovdje riječ najčešće o starijim bolesnicima koji eventualno uzimaju lijekove i za neka druga oboljenja.

Depresija nakon moždanog udara

Depresija se obično razviju u periodu od godinu dana nakon moždanog udara. Pojedini autori smatraju da se ipak razlikuje specifičnijim kliničkom slikom u kojoj se pojavljuje opšta psihomotorna usporenost. Ovakvo stanje se razlikuje od apatije koja se viđa kod bolesnika s frontalnim moždanim udarom.

Hama i saradnici temeljem svog istraživanja 2007. god smatraju da apatija kao protrahirano negativno emocionalno stanje može čak češće nego depresija negativno uticati na oporavak funkcionalnih sposobnosti nakon moždanog udara. Rizični faktori za razvoj depresije nakon moždanog udara su: mjesto lezije i težina udara.. Kao specifične lokalizacije moždanog oštećenja

koje predisponiraju razvoj depresije navode se lijeva hemisfera velikog mozga, područje desnih bazalnih ganglija, lezije bliže frontalnom polu, lezije na nivou paliduma te lezije u području sliva srednje moždane arterije. Težina udara i težina depresije u uzajamnom su dinamičkom odnosu, ali samo u prvih šest mjeseci nakon udara, a potom jačina poremećaja opada (Radanović-Grgurić, 2008). Ostali činioci rizika za razvoj depresije nakon moždanog udara su: ženski pol, starost, izostanak socijalne podrške i samoća.

Ovi simptomi kod većine bolesnika se održavaju i 12 mjeseci nakon moždanog udara. Umor i slabo svakodnevno funkcionisanje prisutno godinu nakon udara rizik su održavanju depresije i nakon tri godine (Radanović-Grgurić, 2008). Tome najviše doprinose samoća i sadržajno siromašne socijalne relacije dok je višegodišnje održavanje depresije najčešće odraz učinka moždane atrofije.

Vaskularna ili aterosklerotična depresija poseban je oblik depresije s kasnim početkom poslije 65 godina. Povezuje se sa subkortikalnom bilateralnom ishemičnom bolešću malih krvnih žila bijele moždane tvari, tzv. „tihim udarom". Ovdje u kliničkoj slici dominiraju poremećaj raspoloženja, oštećenje izvršnih funkcija, psihomotorna retardacija, te izrazito oštećenje svakodnevnog funkcionisanja. Tjelesni simptomi depresije, kao što su gubitak energije i gubitak apetita s čestim mršavljenjem, pogoršavaju stanje. Kognitivna disfunkcionalnost s teškoćama koncentracije popraćena najčešće usporenošću otežava bolesnikovu saradljivost. Depresivno raspoloženje, depresivne misli bezvrijednosti i beznađa sve do suicidalnih promišljanja predstavljaju izravan otpor mjerama rehabilitacije i neophodnim promjenama životnog stila (Radanović-Grgurić, 2008).

Šestogodišnja prospektivna studija Ostira i sar. iz 2001. god. pokazala je da je kod 2.500 starijih osoba rizik za moždani udar rastao zajedno s porastom težine depresije procijenjene na osnovu CES-D ljestvice za depresiju (RR 1,04 za svaki poen), uz čvrstu negativnu povezanost s afektivno pozitivnim tvrdnjama.

Biološki faktori

Većina bioloških teorija depresije zasniva se na deficitu monoamina u sinaptičkim pukotinama u mozgu. Kod depresivnih bolesnika postoje izvjesni patofiziološki problemi koji pogoduju razvoju cerebrovaskularnih i kardiovaskularnih poremećaja.

- Hiperaktivnost hipotalamo-hipofizno-adrenalne osovine;
- Disfunkcija autonomnog nervnog sistema: kod depresivnih je pojačana aktivnost simpatičkog nervnog sistema, što pospješuje ventrikularnu iritabilnost;
- Aktivacija inflamatornog odgovora: kod depresivnih bolesnika povišen je broj T ćelija, makrofaga i monocita. Stres je glavni pokretač aktivacije makrofaga i mikroglije;
- Hierkoagulabilnost: serotonin učestvuje u procesu agregacije trombocita.

Ponašajni faktori

Depresivni bolesnici nedovoljno su fizički aktivni. Pokazuju sklonost lošim navikama: pušenju i alkoholu i često pretjeranom konzumiranju hrane, što pospješuje hiperkolesterolemiju i indirektno razvoj bolesti krvnih sudova.

Psihološki faktori

Osobe sklone ovim bolestima poznate su kao ličnosti tipa A. To su pretjerano aktivne i zahtjevne osobe s nemogućnošću opuštanja, agresivne i ambiciozne. Međutim, psihodinamski gledano, one su nesigurne, niskog samopoštovanja i primarno depresivne pozicije. Stresni događaj, pri čemu je glavna psihološka varijabla gubitak, bilo racionalni ili iracionalni kod osoba sa predispozicijom je najčešći neposredni pokretač nepovoljnih događanja koji mogu završiti vaskularnim incidentom. Još je rizičnije stanje hroničnog stresa. Posljedice stresa mogu direktno i indirektno dovesti do nepovoljnog ishoda.

REZULTATI PRETHODNIH ISTRAŽIVANJA

Najčešći problemi sa kojim se psiholozi i kliničari suočavaju u kliničkoj praksi je diferencijalna dijagnostika Alchajmerove bolesti i depresije. Poznato je da ACE-R može razlikovati kognitivne disfunkcije uzrokovane depresijom od onih zbog demencije, mada ovo nije potvrđeno u svim istraživanjima. Jedna od studija imala je za cilj procijeniti korisnost ACE-R za razlikovanje depresije u kasnom životu (sa teškom epizodom) od blage-umjerene Alchajmerove bolesti (AD) (Rotomskis, i sar., 2015). Ova studija je dobila odobrenje od Litvanskog komiteta za bioetiku. Svi učesnici su bili stariji od 50 godina (srednja starost = 66,52 (±8,76) godina). Uzorak istraživanja sastojao se od 295 osoba: 117 sa teškom depresijom, 85 sa blagom-umjerenom Alchajmerovom bolešću (AD) i 94 osobe koje su odgovarale dobi, polu i obrazovanju ispitanika kontrolne grupe. Rezultati su pokazali da je ACE-R imao visoku osjetljivost (100%) i specifičnost (81%) u otkrivanju kognitivnih oštećenja povezanih s AD. Pacijenti s kasnom depresijom (ACE-R prosjek 76,82, SD = 7,36) imali su lošije rezultate od kontrolne grupe (ACE-R prosjek 85,08, SD = 7,2), ali bolje od AD grupe (ACE-R prosjek 54,74, SD .=1 1). Učesnici sa kasnom depresijom razlikovali su se prema blagim oštećenjima u ukupnom rezultatu ACE-R sa blagim pamćenjem (13,79, SD = 6,29) i većim deficitom u tečnosti slova (3,65, SD = 1,21) nego u semantičkoj tečnosti (SD4.4.4). = 1,23). Učesnici sa AD razlikovali su se po teško oštećenim performansama pažnje i orijentacije (11,80, SD = 2,93), pamćenju (8,25, SD = 3,47) i jezičkim subtestovima (17,21, SD = 4,04) i umjerenim performansama (7,7 verbalno). SD = 2,74). Ovim istraživanjem moglo se zaključiti da ACE-R ima dijagnostičku tačnost u otkrivanju osoba s AD i može se koristiti u diferencijalnoj dijagnostici depresije koja počinje u kasnom životu (teška epizoda) i AD. Dijagnostička tačnost se može poboljšati analizom neuropsiholoških profila i korištenjem nižih granica za različite starosne grupe.

Istraživanju Salak-Đokić (2018) se bavilo ispitivanjem prediktivne vrijednosti odabranih neuropsiholoških testova u dijagnostici blagog kognitivnog poremećaja i demencije i brojao je uzorak od 444 ispitanika, koji su većinom sačinjavale žene, a uzrast ispitanika bila je između 60 i 89 godina. Ovim istraživanjem je utvrđeno da kada je potrebno razlikovati kognitivne promjene karakteristične za proces normalnog starenja u odnosu na početni pad u BKP i umerenu demenciju u sklopu AB, svi ispitivani testovi zadovoljavaju kriterijume dijagnostički validnih instrumenata, od čega se, izdvajaju Adenbrooke test procjene kognicije - Revidirana forma, kao opštedijagnostički test i testovi verbalnog deklarativnog pamćenja (Rejov test auditivnog verbalnog učenja i Tests lobodnog i selektivno potpomognutog podsećanja-Grober - Buschke). Ispitujući dijagnostičku moć testova i kognitivnih domena dobijene su granične vrijednosti i odgovarajuće mjere senzitivnosti i specifičnosti koji mogu da budu korisni u kliničkoj praksi za ispitanike. Kao test sa najvećom diagnostičkom moći izdvaja se ACE-R, sa graničnim skorom 82,5 u razlikovanju zdravih od kliničke populacije i 70,5 kao distinktivan za demenciju, sa visokim vrijednostima senzitivnosti i specifičnosti, u slučaju obe granične vrijednosti (iznad 0.800). Kod razlikovanja zdravih od osoba sa BKP, kao visoko diskriminativni izdvajaju se testovi verbalnog epizodičkog pamćenja u domenu: Neposrednog učenja i pamćenja (RAVLT) sa graničnim skorom 37,5, i Odloženog spontanog prisjećanja (FCSRT - GB) za granični skor 5,5. U slučaju oba parametra vrijednosti senzitivnosti i specifičnosti su visoke (iznad 0.800). U razlikovanju osoba sa BKP i onih sa demencijom, dijagnostički moćnije je Odloženo potpomognuto prisjećanje (FCSRT - GB), sa graničnim skorom 9,5 kao i Ukupno prisjećanje (Totalni skor) - 27,5, u oba slučaja sa vrlo visokom vrijednošću senzitivnosti (>0.900) u odnosu na nešto nižu specifičnost (0.773 i 0.765).

Istraživanje Larnera, A.J. I Mitchella, J.A. (2013) se bavilo meta-analizom tačnosti Addenbrookeovog kognitivnog pregleda (ACE) i Addenbrookeovog kognitivnog

pregleda-revidiranog (ACE-R) u otkrivanju demencije. Objavljene studije koje su upoređivale ACE, ACE-R i MMSE bile su kritički procijenjene. Provedena je meta-analiza odgovarajućih studija. Od 61 moguće identifikovane publikacije, meta-analiza kvalifikacionih studija obuhvatila je 5 za ACE (1090 učesnika) i 5 za ACE-R (1156 učesnika) od njih, 9 je napravilo direktna poređenja sa MMSE. Osetljivost i specifičnost ACE bile su 96,9% (95% CI = 92,7% do 99,4%) i 77,4% (95% CI = 58,3% do 91,8%); a za ACE-R su 95,7% (95% CI = 92,2% do 98,2%) i 87,5% (95% CI = 63,8% do 99,4%).

U okruženju skromne prevalencije, kao što je primarna njega ili opšte bolničke ustanove gdje prevalencija demencije može biti približno 25%, ukupna preciznost ACE (0,823) bila je inferiorna u odnosu na ACE-R (0,895) i MMSE (0,882). U okruženjima visoke prevalencije, kao što su klinike za pamćenje, gdje prevalencija demencije može biti 50% ili veća, ukupna preciznost je opet išla u prilogu ACE-R (0,916) u odnosu na ACE (0,872) i MMSE (0,895). Zaključilo se da ACE-R ima nešto bolju dijagnostičku tačnost od MMSE, dok se čini da ACE ima lošiju preciznost.

Razlikovanje idiopatske Parkinsonove bolesti od atipičnih parkinsonovih sindroma je vrlo osjetljivo, naročito u ranim fazama. Iz tog razloga, Ritman i sar., (2015) bavili su se ispitivanjem da li revidirana Addenbrookova skala može razlikovati Parkinsonove sindrome i odražavati longitudinalne promjene kod ovih poremećaja. ACE-R je primijenjen na početku i nakon 18 mjeseci na 135 pacijenata sa parkinsonskim poremećajima: 86 sa idiopatskom Parkinsonovom bolešću (PD), 30 sa progresivnom supranuklearnom paralizom (PSP), 19 sa kortikobazalnom degeneracijom (CBD). Procijenjivale su se razlike između grupa za ACE-R, ACE-R podrezultate i rezultate MMSE na početku, te interakciju između dijagnoze i promjene ACE-R rezultata između posjeta. Rezultati ACE-R podskor verbalne tečnosti razlikovao je PSP i PD sa visokom osetljivošću (0,92) i specifičnošću (0,87); ukupan ACE-R skor i vizualno-prostorni podskor bili su manje specifični (0,87 odnosno 0,84) i osjetljivi (0,70 i 0,73). Pronađene su značajne razlike na nivou grupe između PD i PSP za MMSE i ACE-R (ukupni skor i podrezultati za pažnju i koncentraciju, tečnost, jezik i vizualno-prostornu funkciju), i između PD i CBD za ACE-R vizuoprostorni podrezultat. Učinak se pogoršao između posjeta za ACE-R skor u PD (p=0,001) i CBD (p=0,001); vizuoprostorni podrezultat u PD (p=0,003), PSP (p=0,022) i CBD (p=0,0002); i MMSE u CBD (p=0,004). Zaključak ovog istraživanja bio je da ACE-R može odražavati progresiju bolesti u PD i CBD, te da ova revidirana skala daje doprinos diferencijalnog dijagnozi Parkinsonove bolesti.

REZULTATI I DISKUSIJA

Primjena ACE-R na zdravom ispitaniku

Ispitanica Z.M., 60 godina, iz Banja Luke, po zanimanju diplomirani pravnik, zaposlena, desnoruka. Udata, majka dvoje djece. Ispitanica je izabrana zbog sličnih karakteristika (istog su pola i približno istih godina starosti). U utvrđivanju psihičkog zdravlja ispitanice korišćen je MCMI III upitnik ličnosti. Iako nivo obrazovanja ispitanica nije isti, dobijena je slična bazična (pasivno-zavisna) struktura ličnosti kod obe ispitanice, što je bio još jedan kriterijum za uključivanje u istraživanje.

Nakon objašnjenog uputstva, počelo se sa radom. Na sljedećim podgrupama ispitanica ostvaruje maksimalan broj bodova i pokazuje izrazitu sigurnost svojim odgovorima: vremenska orijentacija, prostorna orijentacija, pažnja i koncentracija, kao i pamćenje (Tabela 1). Na suptestu Pamćenje ispitanica takođe ostvaruje maksimalan broj bodova i pokazuje priličnu zainteresovanost za svaku podgrupu (Tabela 1). Nesigurnost i anksioznost se pojavljuju kod fonemske fluentnosti, gdje ispitanica ostvaruje skor 4 (navela je 8 riječi) i kategorijalne fluentnosti gdje takođe ostvaruje skor 4 (navela je 12 riječi) (Tabela 1). Ostatak testa je takođe uspiješno riješen, te ukupan broj bodova iznosio je 94.

Tabela 1. Ostvareni bodovi na ACE-R testu kod ispitanice Z.M.

	Ukupan broj bodova
MMSE	30/30
ACE-R	94/100
Podgrupe	**Bodovi**
Pažnja/Orjentacija	18/18
Pamćenje	26/26
Fluentnost	8/14
Jezik	26/26
Vizuospacijalne sposobnosti	16/16

Primjena ACE-R na ispitaniku sa uspostavljenom dijagnozom depresije nakon moždanog udara

Ispitanica M.S., 58 godina, sa dijagnozom depresije nakon moždanog udara. Po zanimanju je ekonomski tehničar, trenutno na bolovanju, a inače je zaposlena kao administrativni radnik u građevinskoj firmi. Udata, ima troje djece. Moždani udar se desio 2023. godine u avgustu, a simptome depresije ispitanica je uočila četiri mjeseca nakon moždanog udara. Simptomi koje je navela bili su sljedeći: smanjen apetit, izrazito smanjena koncentracija i pažnja, poremećaj spavanja, gubitak interesovanja za aktivnosti u kojima je prije uživala (npr. duge šetnje po šumi), nedostatak energije za obavljanje svakodnevnih aktivnosti i gubitak interesovanja za okolinu. Ekspoloracija je vršena u domu zdravlja, a dijagnoza depresije je postavljena od strane psihijatra i psihologa, te je zbog moždanog udara rađena provjera prisustva eventualnog organskog moždanog propadanja, koja nije evidentirala prisustvo istog.

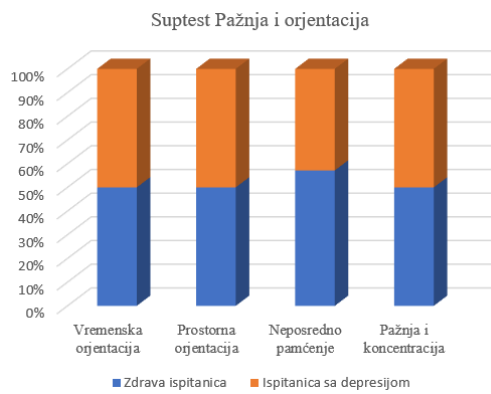
Važno je napomenuti da je bilo izrazito teško sa ispitanicom započeti testiranje zbog raznih pitanja koje je postavljala, a koja se istog tiču, ali i vođenje kroz sam test je iziskivalo mnogo truda i strpljenja. Dolazilo do gubitka motivacije za učešćem u istraživanju. Ovo je posebno evidentno u dijelu ispitivanja fluentnosti, gde je postigla najmanji broj bodova. (Tabela 2). Najbolje rezultate ispitanica je ostvarila na suptestu Govor i jezik (Tabela 2), gdje se vidno uključila i pokazala najveću zainteresovanost. Dobar rezultat ostvaren je i na suptestu Pamćenje, što je bilo prilično iznenađujuće, uzimajući u obzir letargično stanje prisutno tokom testiranja, a ipak ovaj suptest zahtjeva određenu koncentraciju (Tabela 2). Suptest Vizuospacijalne sposobnosti takođe pokazuje solidne rezultate (Tabela 2).

Bezvoljnost i smanjena koncentracija su definisale klijenticu tokom rada. Ukupan broj bodova iznosio je 73.

Poremećaji pažnje su u vezi sa teškoćama u kratkoročnim pamćenjem i osobe sa depresijom su obično tokom eksploracije nemotivisane, slabije sarađuju, pa učinak oscilira tokom ispitivanja (Pavlović, 2002), što se može vidjeti i na osnovu rezultazanih na grafikonu 1.

Tabela 2. Ostvareni bodovi na ACE-R testu kod ispitanice sa depresijom

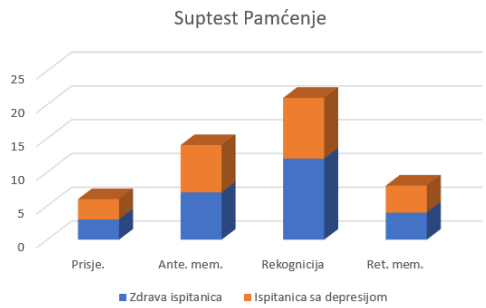
	Ukupan broj bodova
MMSE	19/30
ACE-R	73/100
Podgrupe	**Bodovi**
Pažnja/Orjentacija	13/18
Pamćenje	23/26
Fluentnost	4/14
Jezik	20/26
Vizuospacijalne sposobnosti	13/16



Grafikon 1. Rezultati na Suptestu Pažnja i koncentracija

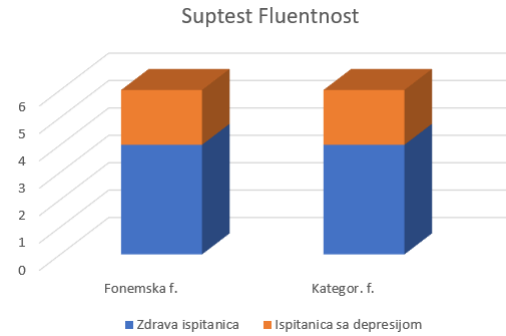
Poređenjem dobijenih rezultata (grafikon 2) zapaža se da su ispitanice podjednako bile uspješne u okviru prisjećanja, anterogradne memorije i retrogradne memorije. Uočljive razlike se evidentiraju u domenu rekognicije, gdje je ispitanica sa depresijom neefikasnija u

odnosu na zdravu ispitanicu. Ovi rezultati se djelimično razlikuju u odnosu na neka ranija istraživanja, a treba napomenuti da ni među dostupnom literaturom nema potpune konzistentnosti u rezultatima. Tako, nešto starije istraživanje Schretlena i saradnika (1995, prema Pavlović, 2002) ukazuje na teškoće sa neposrednim upamćivanjem kod bolesnika sa depresijom, pri čemu se konstatuje da, iako je evokacija slabija ipak postoji pozitivan efekat rekognicije. Totić-Poznanović i saradnici (2005) nisu potvrdili prisustvo poremećaja kratkoročnog pamćenja, rekognicije i semantičkog pamćenja na uzorku osoba sa bipolarnim poremećajem u remisiji. Autori su ovo objasnili nedostatkog kognitivnog napora u kliničkoj grupi, što se može primeniti i na ovu ispitanicu.



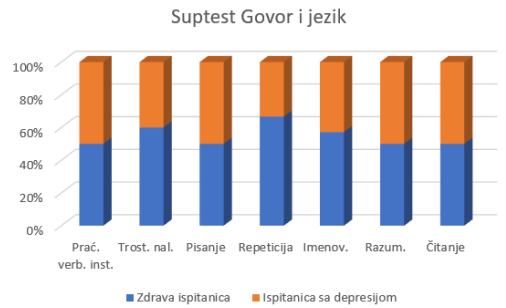
Grafikon 2. Rezultati na Suptestu Pamćenje

Rezultati prikazani u grafikonu 3 pokazuju da je zdrava ispitanica postigla bolje rezultate na suptestu Fluentnost u obe kategorije. S obzirom da testovi verbalne fluentnosti podrazumijevaju sposobnost organizacije i u testnoj su vezi sa egzekutivnim funkcijama, ovaj rezultat je očekivan: gubitak kognitivne fleksibilnosti kod ispitanice sa depresijom rezultirao je i padom verbalne fluentnosti. Ipak, prema nekim nalazima, u ovakvim individualnim procenama treba biti obazriv jer se smatra da rezultat na ovom subtestu zavisi od obrazovanja i starosti (Brickman, & saradnici, 2005, prema Tršinski, & Bakran, 2011), kao i od premorbidnih intelektualnih sposobnosti (Henry, & Crawford, 2004).



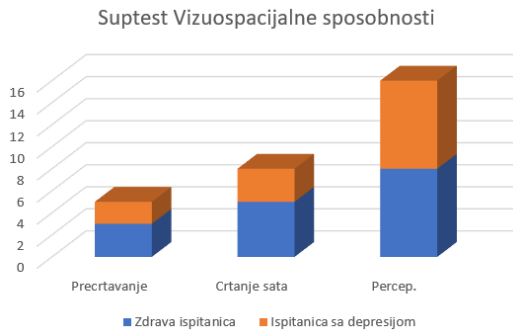
Grafikon 3. Rezultati na Suptestu Fluentnost

Prema rezultatima prikazanim u grafikonu 4, razlike između dvije ispitanice su se ispoljile u okviru izvršenja trostrukog nalaza (koji se odnosi na razumijevanje usmenog govora), repeticije (ili ponavljanja izgovorenog) i imenovanja (odnosno nominacije). S obzirom da postoji uticaj godina starosti i godina školovanja na ove skorove (Pavlović, 1999), dobijene razlike mogu biti povezane sa razlikom u školovanju (zdrava ispitanica je fakultetski obrazovana nasuprot srednjoškolskom obrazovanju ispitanice sa depresijom).



Grafikon 4. Rezultati na Suptestu Govor i jezik

Rezultati iz grafikona 5 ukazuju na teškoće precrtavanja i slabiji uradak na testu crtanja sata kod ispitanice sa depresijom u odnosu na zdravu ispitanicu. Ovo bi moglo da se poveže sa slabijom kognitivnom efikasnošću koju uzrokuje depresija, a koja se odražava u sferi perceptivnih i vizuomotornih sposobnosti.



Grafikon 5. Rezultati na Suptest Vizuospacijalne sposobnosti

ZAKLJUČCI

ACE-R (engl. Adenbrooks Cognitive Examination-Revised, ACE-R) je kombinovani test za ispitivanje globalne kognitivne disfunkcije, a uključuje više kognitivnih domena. Jednostavan je i pogodan za primjenu, te daje znatno detaljnije informacije o odvojenim za razliku od MMSE testa. Revidirana Addenbrookova kognitivna skala (ACE-R) je široko prihvaćena kao globalna skala kognicije, jer uključuje visoku senzitivnost i specifičnost.

Ovaj rad predstavlja prikaz rezultata istraživanja primjene ACE-R testa, kao i interpretaciju i analizu istog kod zdrave ispitanice i ispitanice sa dijagnozom depresije nakon moždanog udara. Obe ispitanice su sličnih karakteristika i godina. Početne pretpostavke da će istraživanje ići dosta jednostavnije sa zdravom ispitanicom su potvrđene. Dakle, u radu sa njom nisu postojale prepreke niti teškoće prilikom testiranja, što nije bio slučaj kada je riječ o ispitanici sa dijagnozom. Zdrava ispitanica je pokazala neznatnu nesigurnost kod fonemske i kategorijalne fluentnosti. Testiranje ACE-R-om kod ispitanice sa dijagnozom bilo je izazovno od samog početka. Pored pomijeranja dogovorenog termina susreta i prilikom samom testiranja postojale su opcije odustajanja od istog, a kao razloge istog ispitanica je navodila težinu pitanja, bezvoljnost i slično. Najlošiji rezultati su postignuti na podgrupama fluentnost i pažnja/koncentracija, što ide u prilog simptomima depresije. Bitno je napomenuti da se depresija kod ispitanice razvila samo četiri mjeseca nakon moždanog udara, što se poklapa sa ranijim istraživanjima (Mihaljević-Peleš, 2022). Pored toga, ranijim istraživanjima utvrđeno je da je ženski pol značajan činilac za razvoj depresije nakon moždanog udara (Radanović-Grgurić, 2008), što je slučaj i u ovom radu.

Poređenjem dvije ispitanice pokazalo se da su kod ispitanice sa depresijom evidentirane teškoće rekognicije zadatog materijala, te da su verbalna fluentnost i vizuospacijalne sposobnosti snižene u odnosu na zdravu ispitanicu. Ovi rezultati se uglavnom mogu objasniti slabijom motivisanošću ispitanice sa depresijom za obavljanje testovnih zadataka (što je posljedica same bolesti), ali se ne može isključiti ni mogući učinak različitog nivoa obrazovanja dvije ispitanice na neke od suptestova.

Značaj ovog rada ogleda se u tome što je još jednom potvrđena validnost ACE-R testa i njegova specifičnost i senzitivnost. Nedostak bi mogao biti mali uzorak, tačnije testirana je jedna zdrava ispitanica i jedna ispitanica sa dijagnozom. Važno je istaći da je prilikom izrade ovog rada uočeno da na našim prostorima postoji vrlo mali broj istraživanja koja su se bavila ovom temom, pa bi ovaj rad mogao biti preporuka za sljedeća istraživanja koja bi obuhvatala veći broj ispitanika.

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RESULTS OF THE APPLICATION OF ADDENBROOKE'S REVISED COGNITIVE TEST EVALUATIONS: COMPARISON OF TWO CASE REPORTS

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ABSTRACT

The ACE-R is a widely accepted instrument in clinical practice, the revisions of which have been overcome certain weaknesses. The aim of this paper was to present the results of the ACE-R test research, and to analyze and compare the results obtained in the work with a healthy subject and a clinical subject diagnosis. The respondents are of similar age and similar characteristics. Selected from the clinical population is a respondent with a diagnosis of depression after a stroke, which is the most common a complication of the same. The results obtained in this paper partially confirmed the results of the previous ones research. The application of the mentioned test showed that the two respondents differed in their views measured abilities: the subject with a diagnosis of depression produces difficulties in recognizing tasks material, and verbal fluency and visuospatial abilities are reduced compared to healthy the respondent.

Keywords: ACE-R, stroke, depression, healthy subject, diagnosed subject.

RENEWABLE ENERGY AND IT'S ROLE IN EXPENDING ACCESS TO ELECTRICITY AND ECONOMIC GROWTH IN NIGERIA

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ABSTRACT

The study investigated, amongst other variables, the relationship between renewable energy, its role in expanding access to electricity, and economic growth in Nigeria over the period 1960–2023. The ordinary least squares (OLS) and autoregressive distributed lag (ARDL) models were used to estimate the short- and long run dynamics of the relationship.

The study shows that the overall model is statistically significant, meaning that the independent variables, taken together, significantly predict the dependent variable (GDP growth rates). The findings underline the intricate dynamics between renewable energy, electricity access, and economic growth in Nigeria. While the positive coefficient for renewable energy suggests that increasing renewable electricity generation could theoretically enhance GDP growth, the lack of statistical significance implies that this impact is not immediate.

Finally, based on these findings, the study recommends that policymakers should continue to prioritize investments in renewable energy infrastructure. Efforts should be made to enhance the reliability and quality of the electricity supply. A more robust and cohesive policy framework is needed to support renewable energy and electricity development and integration.

Keywords: Renewable Energy, Electricity, Economic Growth, Ordinary Least Square, Autoregressive Distributed Lag.

INTRODUCTION

Nigeria, despite being Africa's largest oil producer, struggles with inadequate electricity access. The power sector is plagued by unreliable supply, hampering industrial development, stifling economic growth, and limiting social progress. As of 2020, over half of Nigerians lacked access to reliable electricity, with rural areas

disproportionately affected. The existing energy infrastructure in Nigeria heavily relies on fossil fuels, mainly gas and oil, which are vulnerable to price volatility and geopolitical tensions. This dependency has hindered sustainable development and energy security, exacerbating environmental degradation and contributing to climate change.

Renewable energy sources such as solar, wind, hydroelectric, and biomass offer a sustainable alternative to fossil fuels. Solar power, in particular, holds immense potential in Nigeria, given its abundant sunlight. Initiatives like the Solar Power Naija project aim to install solar home systems across rural communities, providing reliable electricity where the grid does not reach. Expanding access to electricity through renewable sources can catalyze economic growth by enabling industries to operate more efficiently, attracting investments, and creating job opportunities. For instance, the development of solar farms and mini-grids not only boosts local economies through construction and maintenance jobs but also supports small businesses and agricultural and manufacturing sector productivity (Steve, Murad, Gyamfi, Bekun, & Uzuner, 2022).

The Nigerian government has recognized the importance of renewable energy in its National Renewable Energy and Energy Efficiency Policy (NREEEP) Nebo, & Wakil, 2015). This policy framework aims to diversify the energy mix, promote private sector participation, and enhance energy efficiency across sectors. Additionally, initiatives like the Rural Electrification Fund (REF) support renewable energy projects in underserved areas (Akinyemi, et al., 2020). International partnerships and investments play a crucial role in scaling up renewable energy projects in Nigeria. Organizations like the World Bank, African Development Bank, and bilateral donors provide financial and technical support for infrastructure development and capacity building in renewable energy.

Technological advancements in renewable energy, such as improved battery storage systems and more efficient solar panels, are making off-grid solutions increasingly viable and cost-effective (Mohsin, Taghizadeh-Hesary, Iqbal, & Saydaliev, 2022). These innovations reduce reliance on centralized power generation and facilitate decentralized energy systems that are resilient to disruptions. Community involvement is integral to the success of renewable energy projects. Engaging local communities in project planning, implementation, and ownership fosters a sense of ownership and ensures sustainable long-term benefits. Capacity-building programs also empower local stakeholders with skills in installation, maintenance, and management of renewable energy systems. Beyond economic advantages, transitioning to renewable energy mitigates environmental impacts associated with fossil fuel combustion, reducing carbon emissions, combating climate change, and improving air quality, thereby safeguarding public health and ecosystem integrity.

Despite its potential, the adoption of renewable energy in Nigeria faces several challenges, including policy inconsistencies, inadequate infrastructure, financing constraints, and a lack of technical expertise. Overcoming these barriers requires coordinated efforts from government, private sector, and civil society stakeholders. Looking ahead, Nigeria can unlock its renewable energy potential through sustained political will, robust regulatory frameworks, and targeted investments in infrastructure and human capital. Embracing a diversified energy mix with renewables at its core can accelerate progress towards universal electricity access and inclusive economic growth. This study is structured into five sections: an introduction, a literature review, methodology and trend analysis, results and discussion, and policy recommendations to strengthen the role of renewable energy in expanding electricity access and driving economic growth in Nigeria.

SELECTED LITERATURE REVIEW

Literature is replete with studies on electricity performance and its contribution to development and growth, including topics like renewables and electricity, crude oil and agricultural output, electricity prices and economic growth, and investment in energy.

However, studies focusing specifically on renewable energy, its role in expanding access to electricity, and economic growth in Nigeria are sparse, highlighting the need for this research.

Evans (2024) explores the investment dynamics in renewable energy in Africa, using a nonlinear autoregressive distributed lag model. The study finds that rising oil prices increase renewable energy technology (RET) investments through a substitution effect, while falling oil prices decrease them. Additionally, rising GDP boosts RET investment, and declining ICT negatively impacts RET investment.

Idoko et al. (2024) compare renewable energy policies in Nigeria and the USA, examining the political and socioeconomic factors influencing policy formulation and the challenges in implementing renewable energy programs in both countries. Xu, et al. (2024) link energy efficiency, renewable electricity, human capital, and inclusive growth, suggesting government investment in technological development and innovation to enhance access to information and services, boost efficiency, create job opportunities, and support equitable growth.

Amadi, Madu, Ojuka, & Igbogidi, (2024) discuss the prospects and challenges of renewable energy in Nigeria, recommending the development of necessary structures, laws, infrastructure, and technology to harness renewable resources through public-private partnerships. Chanchangi, Adu, Ghosh, Sundaram, & Mallick (2023) highlight factors influencing solar energy adoption in Nigeria, while Muazu, Yu, & Liu (2023) analyze renewable energy consumption's impact on economic growth across 54 African countries, finding a non-linear and negative relationship.

Umeji, et al. (2023) find that renewable energy consumption significantly boosts economic growth in Nigeria using the Toda-Yamamoto augmented Granger causality test and ARDL. Noumba, & Nguea (2023) assess the role of globalization in universal electricity access, concluding that economic, social, and political globalization affect electricity availability, with economic globalization reducing access disparities. This study uniquely focuses on linking access to electricity, renewable energy, and economic growth in Nigeria, aiming to bridge the literature gap and capture energy improvement actions.

METHODOLOGY

The study used for analyzing the renewable energy and its role in expanding access to electricity and economic growth in Nigeria is based on regression analysis. Regression equations of gross domestic product growth rates to control other development indicators such as the electricity to renewable and access to electricity from 1960 to 2023. The data sourced from Central Bank of Nigeria (CBN) Statistical Bulletin and National Bureau of Statistics (NBS), and World Bank Development Indicator. Data set sourced were tested using the Augmented Dickey-Fuller (ADF) Unit root test, Johansen's co-integration test and Autoregressive Distributed Lag Models (ARDL). The stylized form of the regression equation is as follows:

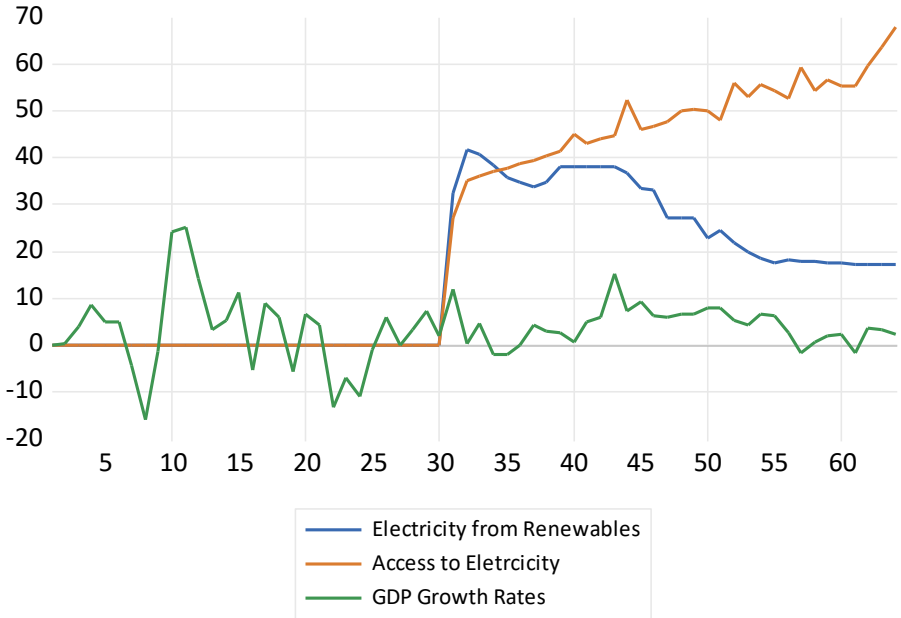

Figure 1. Trend in Electricity from Renewables, Access to Electricity and GDP Growth Rates

Model Specification

$$GDPGRt = \beta0 + \beta1ELECTRENt + \beta2ACCESSELECTAt + \mu t$$

where:
GDPGR = Gross domestic product growth rate
ELECTREN = Electricity from renewable on GDPGR
ACCESSELECT = Access to electricity on GDPGR
μt = Random error term
β0 = Constant term
β1, and β2, = Coefficients for Electricity from renewable and Access to Electricity respectively.

As stated above in the study, the coefficient β1 captures the direct effect of electricity from renewable on GDPGR, while the coefficient β2 captures the direct effect of access to electricity on GDPGR. The gross domestic product growth rates are one of the economic growth indicators of Nigeria indirectly through its impact on the other controlled independent variables. Such indirect effects could be measured by including interaction terms between electricity from renewable and access to electricity as independent variables.

RESULTS AND DISCUSSION

Table 1 below shows the results of a linear regression analysis, where the dependent variable is GDPGR (gross domestic product growth rates) and the independent variables are ELECTREN (Electricity from renewable), and ACCESSELECT (Access to electricity by population).

The coefficient for the constant term (C) is 2.878271, indicating a positive intercept for the regression line. The coefficients for electricity from renewables are positive, while those for access to electricity are negative, suggesting that increases in renewable electricity are associated with higher GDP growth, while increases in electricity access are associated with lower GDP growth. The t-statistics for electricity from renewables are positive, and those for access to electricity are negative. The p-values for all independent variables, except

for electricity from renewables and access to electricity, are greater than 0.05, indicating that they are not statistically significant predictors of GDP growth rate (GDPGR).

The R-squared value of 0.012833 indicates that the model explains only 1.28% of the variation in GDPGR, with an adjusted R-squared of -0.019533. The standard error of the regression is 6.914594, and the sum of squared residuals is 2916.508. The F-statistic of 0.396488 with a p-value of 0.674399 suggests that the overall model is not statistically significant. The Durbin-Watson statistic of 1.149987 suggests no significant autocorrelation in the residuals. Table 2 below presents the results of an Augmented Dickey-Fuller test, with GDPGR as the dependent variable and electricity from renewables (ELECTREN) and access to electricity (ACCESSELECT) as independent variables.

The table presents the results of an Autoregressive Distributed Lag (ARDL) model analyzing the impact of renewable electricity and access to electricity on GDP growth rates (Somoye, Ozdeser, & Seraj, 2022). With a sample of 63 observations and up to four lags for the dependent variable, the optimal model was selected using the Akaike Information Criterion (AIC). The lagged GDP growth rate has a significant positive coefficient (0.420447, p-value 0.0007), suggesting a momentum effect where past economic growth positively influences current growth. However, the variables for electricity from renewables and access to electricity show coefficients of 0.036736 (p-value 0.6640) and -0.008160 (p-value 0.8754), respectively, indicating no statistically significant impact on GDP growth. This suggests that while renewable energy might boost growth, its effect is not robust, and increased electricity access does not necessarily translate into higher GDP growth.

Table 1. Results of a linear regression analysis

Dependent Variable: D (GDP Growth Rates)
Method: ARDL
Date: 06/18/24 Time: 20:13
Sample (adjusted): 2 64
Included observations: 63 after adjustments
Maximum dependent lags: 4 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (4 lags, automatic):Electricity from Renewab
Fixed regressors:C
Number of models evaluated: 100
Selected Model: ARDL (1,0,0)
Note: final equation sample is larger than selection sample

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP Growth Rates (-1)	0.420447	0.117927	3.565327	0.0007
Electricity from Renewables	0.036736	0.084152	0.436542	0.6640
Access to Electricity	-0.008160	0.051813	-0.157500	0.8754
C	1.792468	1.225348	1.462824	0.1488
R-squared	0.186584	Mean dependent var		3.654395
Adjusted R-squared	0.145224	S.D. dependent var		6.887665
S.E. of regression	6.367928	Akaike info criterion		6.601812
Sum squared resid	2392.480	Hannan-Quinn criter.		6.737884
Log likelihood	-203.9571	Durbin-Watson stat		6.655330
F-statistic	4.511217			1.852294
Prob (F-statistic)	0.006468			

Source: Author's computation from Eviews 12.

Table 2. Results of a Augmented Dickey Fuller Test

Null Hypothesis: GDP Growth Rates has unit root
Exogenous: Constant
Lag Length: 0 (Automatic -based on SIC, maxlag=10)
Augmented Dickey-Fuller Test Equation
Dependent Variable: D (GDP Growth Rates)
Method: Least Squares
Date: 06/18/24 Time: 19:22
Sample (adjusted): 2 64
Included observations: 63 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP Growth Rates (-1)	-0.573345	0.115517	-4.963281	0.0000
C	2.111549	0.894415	2.360816	0.0214
R-squared	0.287667	Mean dependent var		0.038254
Adjusted R-squared	0.275990	S.D. dependent var		7.377437
S.E. of regression	6.277372	Akaike info criterion		6.543011
Sum squared resid	2403.729	Schwarz criterion		6.611047
Log likelihood	-204.1048	Hannan-Quinn criter.		6.569770
F-statistic	24.63416	Durbin-Watson stat		1.860355
Prob (F-statistic)	0.000006			

Source: Author's computation from Eviews 12.

Table 3. Results of a Autoregressive Distributed Lag, (ARDL)

Dependent Variable: D (GDP Growth Rates)
Method: Least Squares
Date: 06/18/24 Time: 18:33
Sample (adjusted): 1 64
Included observations: 64

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.878271	1.259280	2.285647	0.0258
Electricity from Renewables	0.054319	0.091193	0.595654	0.5536
Access to Electricity	-0.003428	0.056165	-0.061028	0.9515
R-squared	0.012833	Mean dependent var		3.597296
Adjusted R-squared	-0.019533	S.D. dependent var		6.848035
S.E. of regression	6.914594	Akaike info criterion		6.750886
Sum squared resid	2916.508	Schwarz criterion		6.852084
Log likelihood	-213.0284	Hannan-Quinn criter.		6.790753
F-statistic	0.396488	Durbin-Watson stat		1.149987
Prob (F-statistic)	0.674399			

Source: Author's computation from Eviews 12.

The model's constant term, with a coefficient of 1.792468 (p-value 0.1488), is not statistically significant, indicating that baseline GDP growth rates are not well-determined without considering the independent variables. The R-squared value of 0.186584 indicates that only 18.7% of the variation in GDP growth rates is explained by the model, with an adjusted R-squared of 0.145224, pointing to modest explanatory power. The standard error of the regression is 6.367928, and the Durbin-Watson statistic of 1.852294 suggests no significant autocorrelation in the residuals, enhancing the reliability of the estimates. The F-statistic of 4.511217 (p-value 0.006468) indicates that the model overall is statistically significant, meaning that the combined effect of all predictors significantly predicts GDP growth rates.

Despite the overall significance of the model, the low explanatory power and non-significance of individual variables highlight the need for more comprehensive models that incorporate additional factors. Policymakers should focus on creating an enabling environment that supports economic growth while addressing the complexities of integrating renewable energy and expanding electricity access. This approach can help achieve sustainable economic development and improve the livelihoods of citizens, emphasizing the importance of quality and reliability in electricity supply alongside renewable energy investments.

CONCLUSIONS

This study uses regression analysis to explore the role of renewable energy in expanding electricity access and driving economic growth in Nigeria from 1960 to 2023. Data from the Central Bank of Nigeria, National Bureau of Statistics, and World Bank Development Indicators underwent rigorous testing with the Augmented Dickey-Fuller Unit root test, Johansen's co-integration test, and Auto Regressive Distributed Lag Models. The primary regression model examines how electricity from renewables (ELECTREN) and access to electricity (ACCESSELECT) impact Nigeria's GDP growth rate (GDPGR). Results indicate that while renewable electricity has a positive coefficient suggesting a potential boost to GDP growth, this relationship is not statistically significant. Conversely, access to electricity shows a negative coefficient, though also statistically insignificant, suggesting a more complex relationship. The model's R-squared value of 0.012833 indicates that only 1.28% of the variation in GDP growth is explained by these variables, highlighting the need for more comprehensive factors in the analysis.

The findings underline the intricate dynamics between renewable energy, electricity access, and economic growth in Nigeria. The positive coefficient for renewable energy suggests that increasing renewable electricity generation could theoretically enhance GDP growth, but the lack of statistical significance implies this impact is not straightforward or immediate. The negative coefficient for access to electricity, although not significant, points to potential issues such as the quality and reliability of electricity supply affecting economic outcomes. The relatively low explanatory power of the model suggests that other critical determinants of economic growth, possibly including infrastructure quality, investment levels, and policy effectiveness, were not captured in this analysis.

RECOMMENDATIONS

Policymakers should prioritize investments in renewable energy infrastructure, including both large-scale projects and decentralized solutions like solar home systems and mini-grids, to provide reliable electricity to remote and underserved areas. Enhancing the reliability and quality of electricity supply is crucial, which could involve upgrading grid infrastructure, improving maintenance, and adopting advanced technologies to reduce power outages and technical losses. A robust policy framework supporting renewable energy development and integration is needed, featuring clear regulations, incentives for private sector participation, and mechanisms for policy consistency and stability. Financial constraints can be addressed through

innovative financing solutions such as public-private partnerships, concessional loans, and grants, making renewable energy projects financially viable and attractive to investors. Continued collaboration with international organizations like the World Bank and African Development Bank can offer necessary financial and technical support, scaling up successful initiatives and introducing best practices.

Building technical expertise within the renewable energy sector through targeted training programs, capacity-building initiatives, and international partnerships is essential. Engaging local communities in planning and implementing renewable energy projects can enhance their success and sustainability, ensuring they meet specific local needs. Establishing robust monitoring and evaluation frameworks will help assess the effectiveness of renewable energy projects and policies, enabling continuous improvement based on empirical evidence and feedback. By addressing these recommendations, Nigeria can better harness its renewable energy potential to expand electricity access, drive sustainable economic growth, improve the livelihoods of its citizens, and contribute to global environmental goals.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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UTICAJ DIGITALNOG MARKETINGA NA MODERNO POSLOVANJE I OGLAŠAVANJE

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SAŽETAK

U današnjem svetu, pored povećane globalizacije tržišta i ekonomske regionalizacije, uspešnost poslovanja se zasniva na upotrebi moderne informacione tehnologije. Sama pojava i razvoj Interneta, te umrežavanje preduzeća i javnih administracija doveli su do velikih promena u načinu i efikasnosti rada poslovnih sistema. Omogućena je jednostavna i brza komunikacija, gotovo trenutno prenošenje velikih količina podataka na velike udaljenosti, jednostavno objavljivanje i ažuriranje multimedijalnih dokumenata i njihova kontinuirana globalna dostupnost, digitalna isporuka dobara i usluga, direktno plaćanje putem Interneta, stvaranje virtuelnih organizacija itd. Sve to predstavlja elemente novog oblika poslovanja. Elektronsko poslovanje je opšti koncept koji obuhvata sve oblike poslovnih transakcija ili razmene informacija koje se izvode korišćenjem informacione i komunikacione tehnologije i između: preduzeća, preduzeća i njihovih kupaca, ili preduzeća i javne administracije.

Ključne reči: globalizacija, informaciona tehnologija, internet, komunikacija, elektronska trgovina.

UVOD

Elektronsko poslovanje uključuje i elektronsko trgovanje. Može se posmatrati iz više različitih pravaca:

- sa aspekta komunikacija - elektronsko poslovanje je elektronska isporuka informacija, proizvoda i usluga i elektronsko plaćanje korišćenjem računarskih i drugih komunikacijskih mreža;
- sa poslovnog aspekta - elektronsko poslovanje je primena tehnologije u svrhu automatizacije poslovnih transakcija i poslovanja;
- sa stanovišta usluga - elektronsko poslovanje je alat koji omogućuje smanjenje troškova poslovanja uz istovremeno povećanje kvaliteta i brzine pružanja usluga.

Omogućeni su raznovrsni oblici poslovanja, a samo poslovanje je postalo jeftinije, pa su i mala preduzeća dobila mogućnost korišćenja elektronskog poslovanja. Demokratizacija poslovanja približila je globalno tržište malim i srednjim preduzećima. Korišćenje računara i mreža nije više privilegija velikih i bogatih preduzeća, već se u trku na globalnom tržištu mogu uključiti i najmanja preduzeća. Rizik neblagovremenog uključivanja u savremeno poslovanje je zaostajanje i gubljenje pozicija na tržištu (Radenković, Despotović, Bogdanović, Barać i Labus, 2015).

DIGITALNI MARKETING

Pod pojomom digitalni marketing se podrazumevaju sve online ili elektronski bazirane aktivnosti koje pružaju mogućnost proizvođačima robe i usluga da zadovolje potrebe i želje svojih kupaca na brz i efikasan način. Drugi naziv za digitalni marketing, takođe je i elektronski marketing.

Implementacija e-marketinga se zasniva na određenom broju resursa, od kojih se najčešće izdvajaju: Online informacije i baze podataka (uglavnom bazirani na Webu), koji uključuju:

- aplikacije i promotivne svrhe;
- geodemografske i psihografske pakete programa;
- online servise za podršku kupcima, prodaji;
- pakete za online (interaktivno) istraživanje;
- video konferencije;
- ″smart″card resursi telefonije (mobilna telefonija ,fax, pejdžeri, telemarketing);
- mrežni (network-based) resursi (Internet, Web, intranet,ekstranet, EDI);
- posebni resursi u okviru maloprodaje (optički čitači-skeneri, elektronski kiosci).

Razvoj Interneta je značajno uticao na smanjenje troškova marketinga njegovim globalnim dometom i multimedijalnim aspektom. Drugim rečima, sve ono što je prezentovano na Internetu i jeste marketing. Web sajtovi takođe poseduju marketinšku funkciju, osim njih na Interentu postoje i sasvim konkretne mogućnosti za oglašavanje i promociju. Web prezentacija nekog preduzeća pruža detaljne podatke o proizvodima i uslugama koje preduzeće nudi, pruža mogućnost posetiocima sajta da postave pitanje o željenim proizvodima i uslugama, kupovanje proizvoda... Osim navedenih mogućnosti, kupci mogu na različite načine da steknu znanje o korišćenju proizvoda, kao i rešavanje različitih vrsta problema koji mogu da nastanu prilikom njihove upotrebe. Pored pomenutih karakteristika, bitno je napomenuti da u poređenju sa klasičnim metodama troškovi komunikacije su znatno niži.

Internet je svojom pojavom kao prodajni kanal na neki način ograničen specifičnim karakteristikama proizvoda koji se prodaje. Osim prodaje karakteriše ga i način komunikacije sa tržištem. Njegova stalna dostupnost omogućava korisnicima da sami odaberu kada će pristupiti Web stranicama (što nije slučaj i kod televizije), na taj način korisnik će lakše prihvatiti sadržaj određene stranice i informacije kako tražene, tako i one koje se nude na samoj stranici. Veliku prednost u odnosu na tradicionalne medije može da predstavlja i osvežavanje sadržaja koji se nalazi na Web-u, tj. uvek se mogu pronaći nove informacije na istom mestu za traženi proizvod.

Masovni mediji se odnose na veliki broj potencijalnih kupaca, u većini slučajeva bez dvosmerne komunikacije, za razliku od e-marketinga gde je situacija drugačija i znatno povoljnija u odnosu sa kupcima (Viktor, 2013; Đurić, Ilić i Đekić, 2023).

Korisnost e-marketinga kupac/prodavac

Ukoliko bi bila posmatrana korisnost e-marketinga, postoje dva aspekta:

- Aspekt kupca;
- Aspekt Prodavca.

Najbitnije stavke kada je u pitanju aspekat kupca:

- Raspoloživost narudžbine 24h (kupci nisu vremenski ograničeni prilikom kupovine);
- Nema fizičkog kontakta (ne postoji suočavanje kupca i prodavca);
- Raspoloživost informacija (stvaraju se informacije do kojih se može doći na

vrlo brz i lak način, kao i iskustva korisnika istih ili sličnih proizvoda i usluga).

Kod aspekta prodavca, značajne karakteristike su (Radenković i sar. 2015):

- Globalna prisutnost (širina auditorijuma);
- Kontakt sa potrošačima (sticanje znanja o njihovim potrebama);
- Optimalno prilagođavanje tržištu uz adekvatno praćenje konkurencije.

Interaktivnost digitalnog marketinga

Komunikacija sa potrošačima predstavlja jednu od najznačajnijih performansi e-marketinga. Na primer ukoliko se nekom korisniku odgovori e-mail-om, osim što dobije odgovor, dobija i informaciju o tome da neko održava sajt, da će na njemu moći da izvrši određene pretrage i postavlja pitanja i tako steći poverenje. Na taj način se gradi lojalnost korisnika, dobar imidž i ime preduzeća kao i sam broj posete stranici. Interaktivnost pruža mogućnost prilagođavanja u komuniciranju tj. da se adresira pojedinac, ali i da se dođe do reagovanja tog pojedinca.

Internet omogućava interaktivnost i komunikaciju sa publikom. Posmatrač može da učestvuje aktivno praćenjem prezentacije i da tako dođe do željenih informacija. Komunikacija koja se odvija putem Interneta je brza i jeftina, u odnosu na dosadašnje klasične vizuelne i audio medije ne postoji potreba da se pasivno čeka na određenu informaciju, dok u odnosu na štampane medije sam proces pretrage i dolaženja do informacija nije komplikovan i dugotrajan (Mesaroš, Đokić i Fabian, 2009).

ELEKTRONSKO POSLOVANJE

Razvoj elektronskog poslovanja

Kako bi se napredovalo u pogledu jednostavnije i brže međusobne komunikacije između pravnih lica i firmi, uključujući i transfer novca primarno se razvilo elektronsko poslovanje. Sada je svoj pravac pronašlo u usmerenju ka finalnim korisnicima i njihovim uslugama, odnosno proizvodima. U savremenim uslovima elektronsko poslovanje je sjedinilo preduzeća, klijente i sektore javne uprave. Preduslovi koji su neophodni za implementaciju elektronskog poslovanja su:

- Razvijena primena interneta;
- Razvijena telekomunikaciona struktura;
- Prihvatanje elektronskog poslovanja od strane rukovodstva;
- Finansijska ulaganja za uvođenje.

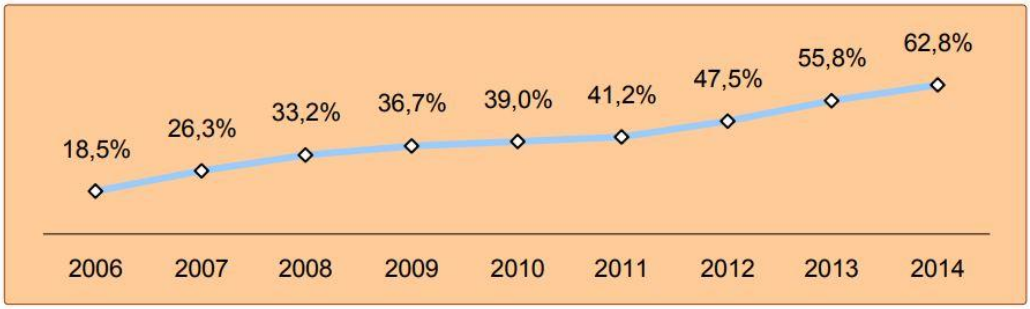
Pojavom Interneta stvorio se jedan od mogućih kanala za prenos informacija, koji je svima dostupan. U tržišno razvijenim zemljama, kao i u vladinim ustanovama (javnim i državnim upravama) komunikacija se sve češće odvija upravo preko Interneta. Postoji nekoliko modela elektronskog poslovanja koji se odvijaju po sličnom principu, njihov zadatak je da obezbede međusobnu razmenu dobara između kompanija i javnih uprava, kao i komunikaciju javnih uprava sa poslovnim partnerima. Jedan od primera moždeda bude popunjavanje obrazaca preko web-a koji su blisko povezani sa poslovanjem kompanija ili pružanje informacija o javnim tenderima, nabavkama, itd. Transakcije koje se obavljaju putem Interneta mogu da se posmatraju kao samouslužni servisi koji će doprineti uštedi vremena i smanjenju troškova, građanima omogućuje uštedu vremena i pruža tekuću i tačnu informaciju (Šarac, Radovanović i Jevremović, 2018; Stojanović 2014).

Aktuelni trendovi elektronskog poslovanja

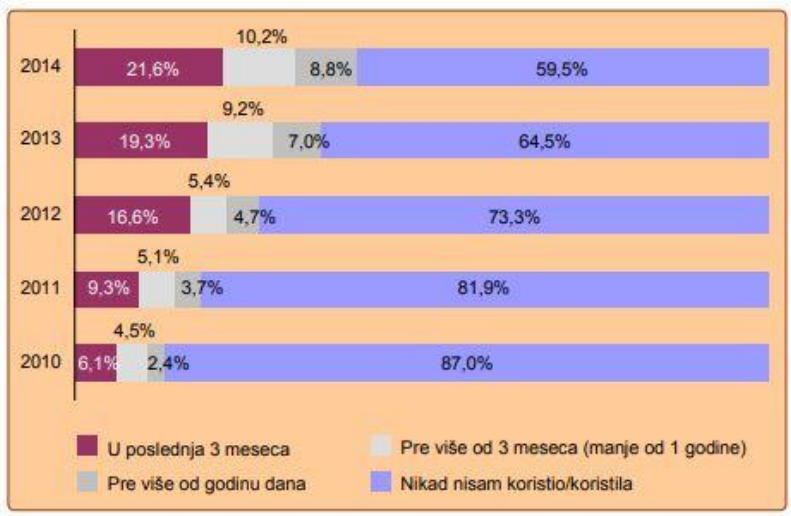
U proteklih nekoliko godina, komunikacija građana sa javnim institucijama postaje sve intenzivnija. Ukoliko se uzme podatak iz perioda od 2008. godine do 2014. godine, može se primetiti kontinualan rast korišćenja Interneta kao komunikacionog posrednika pojedinaca i institucija od javnog značaja za sve zemlje Evroprske Unije.

Prema podacima o vremenskom okviru u kojem su korisnici interneta obavljali kupovine ili poručivanja putem interneta, 21,6% korisnika je izvršilo kupovinu u poslednja 3 meseca, dok je 10,2% to učinilo pre više od 3 meseca, ali manje od godinu dana. S druge strane, 8,8% korisnika je kupovalo ili poručivalo robu ili usluge pre više od godinu dana. Međutim, čak 59,5% korisnika interneta nikada nije koristilo ovaj način kupovine. U poređenju sa 2013.

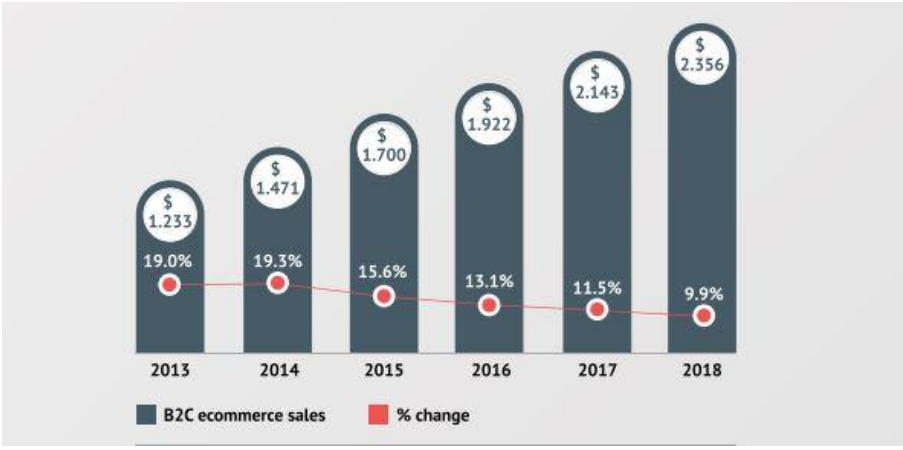
godinom, broj osoba koje su kupovale ili poručivale putem interneta porastao je za nešto više od 260.000. (Vukmirović, Pavlović i Šutić 2014).



Slika 1. Domaćinstva koja imaju pristup Internetu (Vukmirović, Pavlović, Šutić, 2014)



Slika 2. Primena Interneta prilikom kupovine/poručivanja (Vukmirović, Pavlović, Šutić, 2014)



Slika3 . B2C prodaja putem e-trgovine u svetu (Birovljev, 2016).

B2C (komunikacija kompanije sa internetom) prodaja putem e-trgovine u svetu doživela je značajan rast, dostigavši iznos od 1,671 triliona dolara u 2015. godini, prema podacima kompanije eMarketer. Ovaj rast od skoro 25% u odnosu na prethodnu godinu ukazuje na ubrzanje online kupovine. Kako se upotreba interneta širi i postaje sve češća, očekuje se da će se rast e-trgovine u budućnosti smanjivati, ali će i dalje ostati značajan, sa stopom rasta od oko 18% do kraja projektovanog perioda. Ovaj trend ukazuje na stabilan i kontinuiran razvoj tržišta, pri čemu čak i manji rast donosi dodatne stotine milijardi dolara u prihodima, što potvrđuje značajnu dinamiku e-trgovine u globalnoj ekonomiji (Birovljev 2016).

Modeli poslovne komunikacije

Elektronske transakcije se obavljaju između pojedinaca, firmi i državnih institucija, zbog toga postoji nekoliko modela mrežnog poslovanja:

- Komunikacija između kompanija i krajnjih korisnika:
  - Business to Business (B2B) – kompanija sa kompanijom;
  - Business to Consumer (B2C) – kompanija sa klijentom ;
  - Consumer to Business (C2B) – klijent sa kompanijom;
  - Consumer to Consumer (C2C) – klijent sa klijentom;
  - Business to Employee (B2E) – kompanija sa zaposlenim;
  - Employee to Business (E2B) – zaposleni sa kompanijom.

- Komunikacija u elektronskoj vladi
  - Business-to-govemment (B2G) – kompanija sa javnom i državnom upravom;
  - Govemment-to-business (G2B) – javna i državna uprava sa kompanijom;
  - Govemment-to-govemment (G2G) – javna i državna uprava sa javnom i državnom upravom;
  - Govemment-to-consumer (G2C) – javna i državna uprava sa klijentom.

- Višestruke transakcije:
  - Business to Business to Consumer (B2B2C) – kompanija-kompanija-klijent;
  - Consumer to Business to Consumer (C2B2C) – klijent-kompanija-klijent
  - Peer to Peer (P2P).

Ključni faktori u elektronskom poslovanju su: javna i državna uprava (Govemment), kompanija (Business) i klijent (Consumer) (Tabela 1).

Tabela 1. Modeli elektronskog poslovanja i njihove relacije

	Javna i državna uprava	**kompanija**	**Klijent**
Javna i državna uprava	G2G	G2B	G2C
Kompanija	B2G	B2B	B2C
Klijent	C2G	C2B	C2C

Preduzeće koje se odluči za komunikaciju u kojoj potrošači direktno trguju sa potrošačima (C2C), treba da bude pripremljeno na specifičan način obračuna cene usluge koja je najčešće malog procenta u odnosu na kompletnu kupoprodajnu transakciju (plaćanje članarine). Pojedinac se bavi pripremom proizvoda za tržište, postavkom proizvoda na aukciju ili prodaju, uz pomoć tržišnog posrednika (online market) koji obezbeđuje kataloge, pretraživače i servise za komplementiranje transakcija. Na tajnačin se direktno izvršava prodaja. Što više aukcijskih sajtova, online

marketa i markera pruža mogućnost potrošačima da ponude svoju robu i usluge zainteresovanima. Dakle, očekivanja će biti ispunjena ukoliko proizvod na adekvatan način bude predstavljen, a njegovo ponalaženje bazirano na osnovu različitih kriterijuma, kao i proces plaćanja (novčane transakcije).

Vremenom su nastale i različite vrste kombinacija postojećih modela elektronskog poslovanja. B2B2C oblik se pojavio kao rezultat neuspeha mnogih B2C kompanija, kao što su veliki troškovi isporuke. Ovaj lanac povezuje sve karike proizvodnje nekog proizvoda sve do njegove isporuke do krajnjeg kupca. Ovakav model elektronskog poslovanja predstavlja korišćenje B2B modela koji podržava poslovanje nekog preduzeća po modelu B2C, drugim rečima doprinosi uspeh u B2B i zadovoljava potencijalnu tražnju B2C.

Kada se posmatra elektronsko poslovanje na relaciji Klijent-Kompanija-Klijent (C2B2C), može se zaključiti da je to forma koja povezuje kupce preko nekog posrednika. Koristeći online preduzeća kao posrednika, ona uključuje potrošače sprovodeći transakciju sa ostalim potrošačima. Osim pomenutih, uobičajenih kategorija, postoji još nekoliko kategorija e-trgovine kao što su Peer to Peer i M-trgovina (mobilna trgovina). One su kategorizovane više na osnovu tehnologija koje primenjuju, nego na osnovu kriterijuma učesnika u transakcijama.

Peer to Peer tehnologija (P2P), omogućuje korisniku Interneta da direktno deli uslužne fajlove i računarske resurse, preuzima muziku, isključujući opciju obavljanja komunikacije preko centralnog web servera. Pod neposlovnom e-trgovinom se podrazumeva sve veći broj neposlovnih institucija koje koriste takav vid trgovanja da bi smanjile svoje troškove nabavke i povećale kvalitet svojih operacija i religijske i socijalne institucije, vladine agencije itd. Intraorganizaciona e-trgovina obuhvata sve aktivnosti unutar jedne organizacije koje se najčešće ostvaruju na Internetu, a odnose se na razmenu dobara, usluga i informacija (različite modele online edukacije, prodaja proizvoda zaposlenima) ((Radenković i sar. 2015; Terziu, 2020; Aspara, Grant, & Holmlund, 2020).

WEB POSLOVANJE

Posetioci Web prezentacija su isključivo zainteresovani za informacije koje im mogu biti od koristi, pružajući im odgovor na specifične zahteve, potrebe i nedoumice. Još jedan od razloga zbog kojih će posetioci posećivati određenu web stranicu, može da bude i mogućnost dobijanja poklona, dobijanje određene korisne informacije besplatno ili da se besplatno zabave. Upravo takve stranice imaju veće mogućnosti da budu odabrane u tematskim katalozima, da budu bolje ocenjene u diskusionim grupama.

Neki od marketinških aspekata prilikom izgradnje web stranic su (Filipović, 2022):

- Pre kreiranja web stranice potrebno je prethodno izvršiti analizu interesa previđenih posetioca (od zadovoljenja tog interesa zavisi uspešnost same stranice);
- Web mesto zamenjuje skupe telefonske pozivne centre;
- Moževda pruži personalizovane usluge, što korisniku može da bude od koristi ukoliko je potrebno da specificira svoj profil, tj. svoje specifične interese za informacijama;
- Motivisanje posetilaca da ponovo posete web prezentaciju;
- Komunikacija između korisnika sa preduzećem treba da bude takva, da korisnik u što kraćem vremenu dobije odgovor;
- Prezentacija treba da sadrži godišnji poslovni rezultat, referentne liste korisnika, itd.

ELEKTRONSKI SISTEMI PLAĆANJA

Pojavom elektronskog poslovanja kao novog modela biznisa koji je postao zastupljen u savremenom vremenu, neminovno se nameću i promene u finansijskom sektoru. Bilo je neophodno implementirati u novom načinu trgovine i online plaćanje na relaciji peer to peer, odnosno između individualnih učesnika u trgovinskoj transakciji. Osim toga, potrebno je bilo uvesti i mikro-plaćanje, tj. plaćanje malih iznosa, pojava kreditnih kartica i

klasičnih sistema naplate. S druge strane, osim potrebe za novim rešenjima, tehnologija elektronske trgovine je omogućila kreiranje novih sistema naplate ili unapredila postojeće platne mehanizme i sisteme. Osnovu za dalje širenje elektronske trgovine i dalje predstavlja efikasna i sigurna naplata, jer ubiranje prihoda kao i u svakoj trgovini ostaje cilj uspešnog poslovanja i u digitalnom okruženju.

Sitemi za elektronski prenos sredstava predstavljaju prve manifestacije uvođenja tehnoloških inovacija na bazi primene informacione i komunikacione tehnologije tako da preteču e-poslovanja u bankama predstavlja uvođenje informacione i komunikacione tehnologije u sisteme plaćanja.

U savremenim uslovima pojam elektronskog bankarstva predstavlja deo standardne bankarske ponude, dostupnost različitih, prilagodljivih i cenovno konkuretnih bankovnih usluga uz upotrebu modernih tehnologija, postaje temelj današnjeg bankarstva i društva.

Elektronsko bankarstvo predstavlja pokušaj spajanja više različitih tehnologija, od kojih se svaka zasebno razvijala:

- Elektronski novac;
- Platne kartice;
- ATM(bankomati);
- POS terminali;
- Kućno bankarstvo;
- Mobilno bankarstvo.

Tri ključne karakteristike (Grbić i Milošević, 2024):

- Reklamni karakter - informativno predstavljanje je jednosmerna komunikacija gde se banke preko Interneta samo predstavljaju svojim, postojećim ili novim, potencijalnim korisnicima;
- Dvosmerna komunikacija – između korisnika i banke putem e-mail-a ili interaktivnim pristupom nekom servisu;
- Bankarske transkacije na Internetu su najviši nivo komunikacije banke i komiteta.

INTERNET MARKETING

Pod pojmom Internet marketinga se podrazumeva primena Internet tehnologija u realizaciji marketinških aktivnosti, upravo zbog njenih brojnih pogodnosti kao što su: niži troškovi, bliži odnos sa klijentima, veća interaktivnost između prodavca ikupca, jednostavniji proces distribucije proizvoda i usluga, prostor za razmenu ideja, praćenje konkurencije i analiza rezultata. Najčešće se klasifikacija elemenata marketinga oslanja na: proizvod, cenu, distribuciju i prodaju, na ovo se u preduzećima koja se bave prodajom, mogu dodati još i ljudi, proces pružanja usluga i fizička sredina u okruženju u okviru koje se usluga pruža.

Danas, Internet idruštvene mreže imaju sve veći značaj u odnosu na standardne tehnike i elemente marketinga.

Internet marketing predstavlja proces izgradnje i održavanja odnosa sa klijentima preko online aktivnosti kako bi se postigla olakšana razmena ideja, proizvoda i usluga koje je potrebno da zadovolje cilj preduzeća i klijenta. Osnovne komponente Internet marketinga(Šarac, Radovanović i Jevremović, 2018):

1. Upravljanje odnosima sa korisnicima (CRM) – Fokus na korišćenje digitalnih alata za izgradnju i održavanje dugoročnih odnosa sa korisnicima, koristeći podatke o ponašanju korisnika, personalizaciju ponude i automatizaciju komunikacije;
2. Odnosi sa javnošću (PR) – Upotreba digitalnih kanala za upravljanje imidžom brenda, krizno komuniciranje i izgradnju poverenja s publikom putem društvenih medija, blogova i online medija;
3. Razvoj proizvoda i inovacije – Digitalni marketing omogućava praćenje tržišnih trendova, analiza povratnih informacija od korisnika i brzo testiranje novih proizvoda putem online kampanja;
4. Strategije digitalnog marketinga – Definisanje i implementacija marketinških strategija koristeći digitalne alate kao što su SEO (optimizacija za pretraživače), PPC (plaćeni oglasi), email marketing, društvene mreže i mobilni marketing;

5. Marketing tehnike i alati – Korišćenje različitih tehnika kao što su content marketing, marketing na društvenim mrežama, plaćeni oglasi, marketing putem influensera i digitalna analitika za optimizaciju marketinških kampanja i postizanje ciljeva.

Marketing kanali i marketing sredstva (tools)

E-mail marketing

Najisplatljivija i najefikasnija tehnika za promovisanu aktivnost Internet marketinga, kreira zbirke i mail liste adresa zainteresovanih korisnika servisa. Osim što ga karakterišu direktne komunikacije sa korisnicima, predstavlja jeftiniju mogućnost kvalitetnog direktnog marketinga. Da bi se postigla kvalitetna poslovna komunikacija putem mail-a, potrebno je prethodno dobiti dozvolu od korisnika, da na njegovu mail adresu stižu poruke, a takav vid poslovne komunikacije se naziva marketing na osnovu date dozvole.

Viral marketing

Drugim rečima, ovakav marketing se još naziva i virusni marketing. Definiše se kao bilo koja marketing strategija koja stimuliše pojedince da prošire marketinšku poruku drugima. Na taj način se postiže višestruko povećavanje promocije, tehnikom koja donosi najveću korist uz najniže troškove.

Udruženi marketing

Udruženi ili pripojeni marketing dozvoljava vlasnicima web sajtova da postavljaju linkove, banere ili proizvode sa većih sajtova ili pridruženog sajta vlastite stranice. Posetom linka ili izvršenom kupovinom, vlasnik dobija nakandu za podsticanje prodaje. Amazon je prvi uveo ovu tehniku, a nakon toga su je primenili i drugi sajtovi. Postoje četiri vrste modela od prihoda udruženog marketinga:

- Cost per sale – obe strane dele profit od prodaje proizvoda;
- Pay per action –onaj koji oglašava sajt plaća samo definisane akcije koje posetilac sajta izvrši;
- Pay per click –svaka poseta preko postavljene reklame se plaća;
- Cost per mile –svaka hiljadita poseta se plaća u vidu bonusa.

Referral marketing

Osnovni cilj je da se preko usluga, posetilaca ili partnera dođe do povećanja posećenosti, prodaje ili profita. Ovakav vid marketinga sadrži veliki broj varijanti, koje se uvek svedu na to da se preko samo jednog korisnika stigne do dodatna tri posetioca. Za prenošenje pozitivnih utisaka o web sajtu, servisu, proizvodu putem nagrada ili većoj svoti ostvarenog novca u slučaju programa prodaje, koriste se alati Tell a Friend kojima posetilac sajta može poslati e-mail drugim posetiocima i obavestiti ih o postojanju sajta, kao i o nekoj usluzi ili servisu koji postoji na sajtu.

One-to-One marketing

One-to-One marketing je okarakterisan strategijom za upravljanje odnosima sa klijentima, naglašenom personalizovanom interakcijom sa kupcima, a sastoji se od četiri faze:

- Identifikacija potencijalnih kupaca;
- Određivanje njihovih potreba;
- Interakcija sa potencijalnim kupcima;
- Kastomizacija proizvoda, servisa i komunikacija sa svakim kupcem posebno.

Program localhost

Pod programima lojalnosti se podrazumevaju svi promotivni programi kojima je cilj da postignu proces prodaje i ostvare lojalnost putem nagrađivanja redovnih kupaca i onih koji kupuju velike količine proizvoda. Nagrade su raznolike od popusta do robnih nagrada.

Marketing u realnom vremenu i sistemi preporuke

Alati koji spadaju u alate za realizaciju marketinga u realnom vremenu su alati društvenih medija: društvene mreže, blogovi, mikroblogovi, RSS, itd… Osim alata za realizaciju, kada je u pitanju marketing u realnom vremenu, bitno je spomenuti i sisteme preporuke. Njihov zadatak je da predstave tehniku filtriranja informacija, koje pokušavaju da predvide značaj ili preferenciju

korisnika prema nekom traženom pojmu, primenom modela razvijenog na osnovu karakteristika pojma ili korisničkog okruženja. Definisana su dva sistema preporuka: prema osobinama predmeta (pristup prema sadržaju) i prema osobinama korisnika (pristup putem zajedničkog filtriranja). Zadatak sistema preporuke, jeste da pomoću ulaznih elemenata generišu rangiranu listu predmeta koji predstavljaju izlaz. Postoji nekoliko različitih sistema preporuke: preporuke po zajedničkim osobinama, sadržaju, bazi znanja i hibridni sistemi preporuka. Neki primeri za sisteme preporuka su: Amazon, Facebook, Google, YouTube, IMDB, itd. (Petrić, 2024).

Društveni mediji

Označavaju društvenu strukturu određenu vezama i interakcijama između pojedinaca, grupa i organizacija. Internet, kao društvena mreža reprodukuje relacije iz realnog u virtuelni svet, formirajući globalnu platformu za kreiranje i razmenu informacija. Tehnologije društvenih mreža u elektronskom poslovanju obezbeđuju deljenje informacija koje prethodno kreiraju kupci, dobavljači ili poslovni partneri, na taj način da se one transformišu u korisne ideje i rešenja koja svoju primenu mogu da pronađu u poslovanju. Društveni mediji predstavljaju virtuelne zajednice za kreiranje, deljenje irazmenu informacija među korisnicima Interneta, najbolje su opisani preko sedam funkcionalnih blokova (Mesaroš, Đokić i Fabian, 2009; Milić i Đuranović, 2015; Njegomir 2020).:

- Identitet – mera kojom korisnici otkrivaju svoj identitet uokviru društvenih medija. Sadrže informacije kao što su: ime, godine, pol, zanimanje, lokacija…
- Konverzacije – mera međusobne komunikacije korisnika.
- Deljenje – mera u kojoj korisnici razmenjuju, distribuiraju i prihvataju sadržaj.
- Prisustvo – izračunava u kojoj meri jedan korisnik ima informacije o tome da li je drugi korisnik dostupan. Obuhvata informacije o mestu na kojem se korisnici nalaze u virtuelnom ili realnom svetu i da li su dostupni za konverzaciju.
- Veze – mera u kojoj korisnik može da bude povezan sa ostalim korisnicima. Takve veze pružaju mogućnost konverzacije, deljenje objekata, itd…
- Reputacija – mera poverenja u korisnika od strane drugih korisnika medija.
- Grupe – stepen na osnovu kojeg korisnici mogu da kreiraju zajednice i podgrupe. Porastom broja korisnika jedne mreže, broj grupa se povećava, kao i prijatelja, kontakata, itd.

ZAKLJUČAK

Kako razvoj, tako i primena Interneta u pogledu poslovanja kao najvažniji cilj ima upravo ostvarivanje fokusa na korisnika, odnosno na pojedinca i njegove želje i potrebe. Drugim rečima, može se nazvati personalizacijom poslovne komunikacije u domenu elektronskog poslovanja.

Ono što Internet obezbeđuje kupcu jeste upravo direktan poslovni kontakt sa prodavcem, vremenski neuslovljeno i lokaciono neodređeno. Na taj način kupac može da dođe do potrebnih informacija koje mogu biti personalizovane prema potrebama svakog individualnog kupca i obavi kupovinu.

Primenom Interneta prilikom kupovine kupac može da pristupi i informacijama konkuretnih proizvoda i usluga i na taj način izvrši odabir. Sa strane prodavca Internet pruža mogućnost da pronađe nove kupce, opsluži postojeće primenom baze podataka, kako bi na taj način razvili lične profile kupaca i usmerili ih prema određenim informacijama prepoznavajući specifične potrebe kupca.

Implementacija elektronskog poslovanja pruža mogućnost rasta konkurentnosti i bolju poziciju kompanije na tržištu. Elektronsko poslovanje obezbeđuje unutrašnju i spoljnu integraciju preduzeća. Unutrašnja integracija obuhvata elektronsko slanje različitih vrsta poslovnih doukmenata u sve delove preduzeća, informacije su na raspolaganju svima unutar preduzeća i mogu se efikasno pretraživati. Spoljna integracija omogućuje integraciju sa poslovnim partnerima, vladinim agencijama itd. Ona ubrzava,

pojednostavljuje i smanjuje cenu međusobne transakcije.

Jedna od bitnijih karakteristika elektronskog poslovanja je fleksibilnost, mogućnost potpune promene ponude u skladu sa aktuelnom situacijom na tržištu. Osnovne prednosti elektronskog poslovanja su upravo (Milić i Đuranović, 2015): Smanjenje transakcionih troškova; Velike kupovine po transakciji; Objedinjenje celokupnog ekonomsko/prodajnog procesa; Tržištu se nudi drugačiji način kupovine (mogućnost definisanja obima kupovine kroz nekoliko dana, mogućnost izbora proizvoda uz uvid, mogućnost upoređivanja sa konkurentnim preduzećima, mogućnost pretrage velikih kataloga); Obimni katalozi; Unapređivanje interaktivnog odnosa sa kupcima.

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THE IMPACT OF DIGITAL MARKETING ON MODERN BUSINESS AND ADVERTISING

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ABSTRACT

In today's world, alongside increased market globalization and economic regionalization, business success relies on the utilization of modern information technology. The emergence and development of the Internet and the networking of businesses and public administrations, driven by digital marketing strategies, have led to significant changes in how business systems operate and their efficiency. It has facilitated easy and fast communication, almost instant transmission of large amounts of data over long distances, simple publishing and updating of multimedia documents and their continuous global availability, digital delivery of goods and services, direct online payments, creation of virtual organizations, etc. All of these represent elements of a new form of business. Electronic commerce is a broad concept encompassing all business transactions or information exchanges conducted using information and communication technology between: businesses, businesses and their customers, or businesses and public administrations.

Keywords: globalization, information technology, internet, communication, electronic commerce.

Gluhović, D. (2024). Vladavina prava u zemljama Zapadnog Balkana kao fokus politike proširenja Evropske unije. *STED Journal, 6*(2), 84-92.

VLADAVINA PRAVA U ZEMLJAMA ZAPADNOG BALKANA KAO FOKUS POLITIKE PROŠIRENJA EVROPSKE UNIJE

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APSTRAKT

Evropska unija je još 2018. godine usvojila Strategiju proširenja na zemlje Zapadnog Balkana, čime je obezbijeđen potencijalni vremenski i reformski okvir pristupnih pregovora o priključenju ovih zemalja Evropskoj uniji. Jačanje vladavine prava, borba protiv korupcije i organizovanog kriminala su kamen temeljac pristupnih pregovora i evrointegracijskih procesa za zemlje Zapadnog Balkana. U ovom radu je dat osvrt na Strategiju EU – Zapadni Balkan iz 2018. godine pri čemu je fokus stavljen na incijativu za jačanje vladavine prava i analizu stanja u ovim zemljama sa stanovišta vladavine prava.

Ključne riječi: politika proširenja, EU, vladavina prava, korupcija, organizovani kriminal, Zapadni Balkan

UVOD

Proširenje Evropske unije (EU) na zemlje Zapadnog Balkana bio je geopolitički interes ove unije i zemlje ovog regiona su u različitim fazama svojih procesa članstva u EU kao rezultat napretka koji su ostvarili od 1999. godine (Ker-Lindsay, 2017; Grieveson et al., 2021). Zemlje Zapadnog Balkana se ne mogu posmatrati kao jedinstvena cjelina u procesu pristupanja EU, između ostalog jer i zemlje članice EU nemaju isto mišljenje u pogledu pristupanja novih članica EU. Neke od zemlja EU nemaju pozitivne stavove prema regionu Zapadnog Balkana ili pojedinim zemljama ovog regiona. Prema njima, region Zapadnog Balkana ostaje problematičan u smislu ekonomskog razvoja, vladavine prava i političke stabilnosti. U potencijalnim procesima proširenja EU na zemlje Zapadnog Balkana veliki značaj se stavlja na promociju vladavine prava. U ovom radu se stavlja u fokus incijativa za jačanje vladavine prava i analiza stanja u zemljama Zapadnog Balkana sa stanovišta vladavine prava, na evoluciju politike EU prema zemljama Zapadnog Balkana tokom godina i na cilj koji EU želi da postigne reformom pravosudnih sistema u zemljama Zapadnog Balkana. EU je nastojala i nastoji da promoviše vladavinu prava kroz svoju politiku proširenja (Appicciafuoco 2010; Kovačević, 2020). Kako bi inicijativa EU za vladavinu prava imala dugotrajan uticaj u

zemljama Zapadnog Balkana, nije bilo dovoljno fokusirati se samo na ispitivanje i provjere pravosudnih sistema. Analizirani su potencijalni izazovi sa kojima se inicijativa za vladavinu prava suočava u zemljama Zapadnog Balkana, s obzirom na postojanje visokog nivoa korupcije i na političke uslove koji u ovim zemljama nisu povoljni sa aspekta postojanja poluautokratskih sistema i nedostatka političke volje za jačanje vladavine prava.

STRATEGIJA EU ZA PRIDRUŽENJE ZEMALJA ZAPADNOG BALKANA

Evropski savjet je još 2003. godine na samitu u Solunu, proglasio da je budućnost Balkana unutar Evropske unije. Međutim, osim Hrvatske koja je ušla u EU 2013. godine, dvanaest godina nakon samita u Solunu, Srbija, Crna Gora, Bosna i Hercegovina, Albanija i Sjeverna Makedonija, ostaju van EU i bez predvidivog datuma pristupanja. Političke poruke koje dolaze iz Brisela, na koje je u velikoj mjeri uticao uočeni zamor od proširenja unutar same EU i sve veći uticaj država članica na proces pridruživanja, upućuju na zaključak da je evropska integracija Zapadnog Balkana usporena (Kmezić, 2015).

Izbijanje ekonomske krize u eurozoni, krajem 2009. godine, uzrokovalo je da proširenje EU ne bude u fokusu politike EU (Gstöhl, 2016). Međutim, nakon Brexita, Komisija se ponovo okrenula politici proširenja u nadi da će se održati projekat, ideja i vizija EU. U govoru o stanju EU 2017. godine, tadašnji predsjednik Komisije Jean-Claude Juncker izjavio je da bi zemlje Zapadnog Balkana trebale postati budući članovi EU (Belloni, & Brunazzo, 2017). Države članice EU su podržale ideju Komisije o proširenju EU na Zapadni Balkan, čime su politika proširenja i integracija Zapadnog Balkana u EU obnovljene i postavljene kao jedan od prioriteta politike EU. Vladavina prava i pravde trebali su biti centralni kriterijumi u pristupnim pregovorima EU sa zemljama Zapadnog Balkana, kako je i bilo naglašeno u govoru o stanju EU iz 2017. godine (Berger, 2019). U februaru 2018. godine takvi pravci politike praćeni su usvajanjem strategije „Vjerodostojne perspektive proširenja za pojačani angažman EU na Zapadnom Balkanu", koja je uslijedila gotovo petnaest godina nakon posljednjeg samita EU i Zapadnog Balkana u Solunu (European Commission [EC], 2018). Strategija EU - Zapadni Balkan iz 2018. godine je uvela obnovljene ciljeve politike o budućem proširenju EU, posmatrajući Zapadni Balkan kao geostrateški region za EU. Proširenje EU na Zapadi Balkan je mogao biti jedan od pravaca u amortizaciji štetnih posljedica Brexit-a, pri čemu je ispunjavanje uslova vladavine prava navedenih u kriterijima iz Kopenhagena ključno u pregovorima za pristupanje zemalja Zapadnog Balkana u EU (Louwerse, & Kassoti, 2019).

Strategija EU - Zapadni Balkan iz 2018. godine se fokusirala na izgradnju dobrosusjedskih odnosa, u svjetlu dugotrajnih etničkih sporova u regionu. Naglašeno je šest, tzv. vodećih inicijativa, koje su obuhvatale oblasti značajne i za EU i za zemlje Zapadnog Balkana (EK, 2018):

- vladavina prava;
- bezbjednost i migracije;
- društveno-ekonomski razvoj;
- transportna i energetska povezanost;
- digitalna agenda i
- pomirenje i dobrosusjedski odnosi.

Suštinski ove inicijative su obezbjeđivale okvir i gradivne blokove za razvoj eventualnih budućih zajedničkih akcionih planova u svakoj od ovih šest ključnih oblasti, koje bi osmislila Komisija i odgovarajuće vlade zemalja Zapadnog Balkana, kroz tehnički i politički dijalog o reformama koje bi bile usklađene sa Standardima upravljanja u EU (Vunsch, Kmezić, Stratulat, & Tzifakis, 2019).

Inicijativa za vladavinu prava, praćena je teoretskom raspravom o načinu identifikacije ove grupe oblasti koje su označene kao ključne inicijative od strane EU, kao prioritete u reformama koje su neophodne u fazi pristupnih pregovora i kao projektovanje modela upravljanja koji bi bio primjenjiv u zemljama Zapadnog Balkana. Tokom 2019. godine, praktično godinu dana nakon donošenja strategije EU –Zapadni

Balkan, EU je objavila izveštaje o napretku za svaku od zemalja Zapadnog Balkana. U izveštajima Komisija je obično prezentovala preporuke i uvodila uslove koje svaka od država kandidata mora da ispuni da bi mogla da ostvari napredak u smislu pridruživanju EU, što se uglavnom odnosilo na usvajanje zakona i politika u oblastima koje obuhvataju 35 poglavlja koje je neophodno zatvoriti u procesu pridruživanja.

Izveštaji su pružili detaljnu procjenu napretka koje je ostvarila svaka od zemalja Zapadnog Balkana u ispunjavanju kriterijuma za pristupanje EU, a posebno napretka u ispunjavanju kriterijuma koji se odnose na vladavinu prava (Perišić, 2022; Sargentini, & Dimitrovs, 2016). Komisija je takođe, prezentovala i prijedloge 27 država članica EU za sastanak Savjeta na kojem bi se razgovaralo o stanju u zemljama Zapadnog Balkana, posebno naglašavajući ispunjenost kriterijuma iz Kopenhagena u vezi sa funkcionisanjem vladavine prava (Fouéré, 2019). Osnovni prijedlog zemalja članica EU bio je da Komisija identifikuje Srbiju i Crnu Goru kao prve kandidate za pristupanje EU i preporuči da se za obe zemlje omogući pridruživanje EU do 2025. godine (EC, 2018). Dok je ovaj projektovani teoretski datum imao za cilj da ohrabri Srbiju i Crnu Goru da nastave provođenje svojih unutrašnjih reformi u pravcu ispunjavanja *ackuis* EU (pravne tekovine Zajednice - a*ckuis Communautaire*), održivi rezultati i opipljiv napredak u skladu sa kriterijumima iz Kopenhagena, naročito poglavlja 23 i 24 ackuis-a[1], o pravosuđu i osnovnim pravima, kao i bezbjednosti i pravdi su jasno identifikovani kao neophodni, da bi ove dvije zemlje imale bilo kakvu nadu da će se pridružiti EU do projektovanog datuma (Closa, & Kochenov, 2016).

Komisija je predložila da države članice dozvole otvaranje pregovora o pristupanju bez dodatnih preduslova u smislu provođenja reformi, s ciljem jačanja vladavine prava i napretka u ispunjavanju kriterijuma iz Kopenhagena, promenom više od jedne trećine svojih ustava kao glavnog preduslova za otvaranje pristupnih pregovora sa EU (Makul, & Olovčić, 2022; Hoxhaj, 2019) Suprotno tome, Sjevernoj Makedoniji je kao osnovni preduslov postavljeno pitanje rješavanja tridesetogodišnjeg spora oko imena sa Grčkom što je riješeno Prespanskim ugovorom, koji je uključivao promjenu naziva države iz „Bivša Jugoslovenska Republika Makedonija“ u „Republika Severna Makedonija“ (Josifovic, & Kambovski, 2024; Vankovska 2020; Bechev, 2019). Komisija je takođe predložila svojim državama članicama, da se Bosni i Hercegovini dodijeli status kandidata za EU (EC, 2019), a da se Kosovu[2] odobri vizna liberalizacija, što je i realizovano tokom godina koje su slijedile. U zaključcima sastanka Savjeta u junu 2019. godine, 27 država članica EU je prepoznalo napredak postignut na Zapadnom Balkanu na osnovu Izvještaja Komisije (EC, 2019a). Međutim, države članice su istakle da izražavaju zabrinutost u vezi sa usaglašenošću zemalja Zapadnog Balkana sa kriterijumima iz Kopenhagena i nedostatkom vladavine prava, zbog čega u to vrijeme nisu podržale preporuke iz Izveštaja o otvaranju pristupnih pregovora sa Albanijom i Severnom Makedonijom i odobravanje vizne liberalizacije za Kosovo[3] i nisu se obavezali da će Bosni i Hercegovini dati status kandidata za članstvo u EU, iako su države članice predložile da preispitaju prijedlog Komisije za početak pregovora o pristupanju sa Albanijom i Severnom Makedonijom u jesen 2019. godine. Takođe, države članice su navele da su vremenski okvir pristupanja (2025. godina) posmatrali kao izuzetno ambiciozan plan za pristupanje Srbije i Crne Gore Evropskoj uniji. Bez obzira na rezerve i oklijevanje država članica u pogledu konkretnih koraka napredovanja u proširenju EU na Zapadni Balkan, postojao je opšti konsenzus da se podrži cilj spoljne i

[1]Pravne tekovine Zajednice - a*ckuis Communautaire* ili *ackuis* EU predstavljaju akumulirane zakone, pravne akte i sudske odluke, odnosno tijelo prava Evropske unije. Tokom procesa proširenja Evropske unije, ackuis je podeljen na 35 poglavlja u svrhu pregovora između EU i država kandidata za članstvo.

[2]U skladu sa Rezolucijom Ujedinjenih Nacija 1244.

[3]U skladu sa Rezolucijom Ujedinjenih Nacija 1244.

bezbjednosne politike EU kao dugoročna geopolitička strategija i bezbjednosna investicija (Burlyuk, 2020).

VLADAVINA PRAVA KAO OSNOV STRATEGIJE PRISTUPANJA ZEMALJA ZAPADNOG BALKANA U EU

U strategiji EU –Zapadni Balkan iz 2018. godine potvrđeno je da u zemljama Zapadnog Balkana postoje jasni elementi raznih uticaja na rad državnih organa, uključujući veze sa organizovanim kriminalom i korupcijom na svim nivoima vlasti i administracije u zemljama, dok je istovremeno vladavina prava veoma slaba (Richter, & Wunsch, 2020). Shodno tome, inicijativa za vladavinu prava je bila jedna od najvažnijih od šest prezentovanih vodećih inicijativa, i trebalo je da bude u središtu pažnje i od EU i od zemalja Zapadnog Balkana ako bi te zemlje željele da riješe problem "zarobljavanja" države i njenih organa, kao i da se ozbiljno bore protiv korupcije na najvišem nivou (Elbasani, & Šabić, 2018). Osvrćući se na Strategiju EU - Zapadni Balkan iz 2018. godine iz današnje perspektive, jasno je da još uvek nema konkretnih prijedloga niti mape puta za jačanje vladavine prava, već samo pojedini široki ciljevi politike. Strategija je više predstavljala platformu za Zapadni Balkan i Komisiju za dijalog o transformaciji vodeće inicijative za vladavinu prava u zajednički akcioni plan. Reforma pravosudnog sistema je bila krajnji cilj, što je na kraju trebalo rezultovati jačanjem nezavisnih institucija kako bi bile u stanju da održavaju vladavinu prava bez političkog uplitanja (EC, 2019a). Strategija ukazuje da je Komisija trebala blisko sarađivati sa zemljama Zapadnog Balkana kako bi osigurala da se pravosuđe reformiše u skladu sa najvišim standardima EU i kriterijumima iz Kopenhagena, kao i da je trebala ponuditi tehničku i finansijsku podršku u borbi protiv korupcije i organizovanog kriminala u okviru inicijative za vladavinu prava. Ne postoje jasni primjeri da su EU i zemlje Zapadnog Balkana razvile zajednički akcioni plan ili strategiju za borbu protiv korupcije i organizovanog kriminala ili primjeri kako bi se takva saradnja uklopila u opštu inicijativu o vladavini prava, budući da ne postoji zajednički akcioni plan kao direktan rezultat inicijative za vladavinu prava.

U inicijativi za vladavinu prava implicitni princip predstavlja potrebu za jasnom slikom u borbi protiv korupcije i organizovanog kriminala na najvišem nivou, kako bi se pokazala istinska posvećenost suštinskog ispunjavanja kriterijuma koji se odnose i na vladavinu prava i na opšte kriterijume iz Kopenhagena, ako zemlje žele da budu ozbiljno shvaćene u svojim nastojanjima za pridruživanje EU (Radifković, & Ranković, 2020).). Drugim rečima, zemlje Zapadnog Balkana moraju da pokažu da postoje optužnice protiv javnih zvaničnika koji su zloupotrebili položaj, bavili se korupcijom, bili dio ili bili povezani sa mrežom organizovanog kriminala, kao prvi korak dobre volje u ispunjavanju svojih obaveza. Ovo je jasan pokazatelj da EU neće ozbiljno shvatiti zemlje Zapadnog Balkana ukoliko se nastavi političko miješanje u sudske odluke, istrage i optužnice protiv visokih zvaničnika (Hoxhaj, 2019). Štaviše, osnovna poruka inicijative za vladavinu prava je da Komisija planira da iskoristi sve poluge koje su joj na raspolaganju da u okviru pristupnih pregovora odlaže pristupanje zemalja Zapadnog Balkana, kako bi izbjeglo bilo kakvo ponavljanje scenarija Mađarske i Poljske, gde je bilo jasnih elemenata nazadovanja u njihovim opredeljenjima za vladavinu prava (Adamski, 2019; Grabbe, & Lehne, 2017) ili kao što je to bio slučaj sa Bugarskom, Slovačkom i Maltom, gdje su visokoprofilisani političari bili primjetno umiješani u mreže korupcije i organizovanog kriminala.

Postoje određeni znaci da je model rada i upravljanja inicijativom za vladavinu prava zasnovan na Otvorenom metodu koordinacije (OMC), što može pomoći u razumijevanju djelovanja inicijative za vladavinu prava u zemljama Zapadnog Balkana.

NIVO KORUPCIJE I VLADAVINA PRAVA U ZEMLJAMA ZAPADNOG BALKANA

Izvještaji Transparency International (TI) o indeksu percepcije korupcije iz 2019.

godine ukazuju na to da nivoi korupcije u zemljama Zapadnog Balkana ne stagniraju. Osim Crne Gore, svaka zemlja u regionu ostvarila je između 36 i 39 bodova, što ih stavlja između 87 i 99 mjesta od 180 zemalja. Crna Gora i Srbija su zabilježile porast uočenog nivoa korupcije u 2018. godini, dok je Bosna i Hercegovina zabilježila najgori rezultat od 2012. Severna Makedonija i Albanija su najlošije rangirane među zemaljama Zapadnog Balkana (Transparenci International [TI], 2019). Bez obzira na ograničenja koja ima indeks percepcije korupcije (CPI), rezultati zemalja daju koristan pregled za istraživače i kreatore politike o nivou korupcije na Zapadnom Balkanu i mogućim izazovima za inicijativu vladavine prava kao transformacionog sredstva u jačanju vladavine prava u ovom regionu. Trend blagog rasta korupcije u Republici Srbiji u 2019. godini mogao se objasniti podrivanjem institucija koje su odgovorne za održavanje vladavine prava od strane Vlade Srbije. U 2018. godini, uprkos snažnom protivljenju nevladinih organizacija, udruženja advokata i drugih aktivista civilnog društva, vlada se zalagala za povećanje uticaja na pravosuđe (Russell, 2019). Štaviše, vlada je otvoreno prekršila i izmjenila sopstvenu antikorupcijsku politiku, predloženu kao odgovor na Strategiju za borbu protiv korupcije za 2013–2018 i Akcioni plan za Poglavlje 23 u okviru EU integracija (2016–2018). Prema izvještaju TI, pogoršanje nivoa korupcije u Bosni i Hercegovini povezano je sa nepravilnostima izbornih kampanja i novim zakonima koji se odnose na finansiranje političkih partija. Drugim riječima, u Bosni i Hercegovini postoji porast političke korupcije i iako postoje dokazi o izbornoj prevari prema nalazima TI pravosudne institucije do sada nisu bile u stanju da preduzmu mjere za očuvanje vladavine prava (Weber, 2021). Crna Gora je postigla 45 u CPI u 2019. godini, bolje od ostalih država Zapadnog Balkana (TI, 2019). Međutim, korupcija i zarobljavanje države ostaju problematični, jer je Vlada 2019. predložila izmene i dopune „Zakona o tajnim informacijama“. Sjeverna Makedonija u 2019. godini dijeli najgori rezultat na Zapadnom Balkanu zajedno sa Albanijom, sa samo 35 poena u CPI. Izveštaj TI ukazuje na to da je Sjeverna Makedonija ostvarila dobar napredak u borbi protiv korupcije i da se konsoliduje evidencija u procesuiranju i donošenju presuda u slučajevima korupcije na visokom nivou. Međutim, u 2018. i 2019. godini, vladavina prava u zemlji je potkopana do temelja, nakon što je uhapšena njena specijalna tužiteljka za organizovani kriminal i korupciju Katica Janeva, pod sumnjom da je ponudila popustljivost u zamjenu za mito biznismenu optuženom za korupciju. Janevin slučaj je podstakao velika politička previranja u Severnoj Makedoniji i bio je veliki test za sudove da pokažu svoju sposobnost da podrže vladavinu prava. Albanija je u 2019. pala za sedam mjesta u CPI, postigavši 35 bodova od 100 i pala je za 23 mjesta za nešto više od tri godine od početka reforme pravosuđa. Kao rezultat toga, Albanija se smatra najkorumpiranijom zemljom na Zapadnom Balkanu. Izveštaj Fridom hausa za Albaniju, kao i TI su utvrdili da u Albaniji preovladavaju pitanja sukoba interesa, zloupotreba državnih resursa u lične i izborne svrhe, nedovoljno objelodanjivanje finansiranja političkih partija i kampanja, kao i nedostatak nezavisnosti medija (Freedom House, 2020).

Nivoi korupcije na koje ukazuje TI u svim zemljama Zapadnog Balkana jasno ometaju njene šanse da se uspješno kreću u pravcu integracije u EU. Slična situacija sa indeksima percepcije korupcije prisutna je u zemljama Zapadnog Balkana i u 2023. godini, s tim da su Crna Gora i Sjeverna Makedonija pokazale izvjestan napredak. Crna Gora sa 46/100 i Sjeverna Makedonija sa 42/100 plasirane na 63 i 78 mjesto od 180 zemalja, čeme su postale najbolje pozicionirane na Zapadnom Balkanu, dok su Albanija (37/100), Srbija (36/100) i Bosna i Hercegovina (35/100) i dalje na jasko niskom nivou, plasirane na 98, 104 i 108 mjesto od 180 zemalja svijeta (TI, 2023).

U ovim uslovima, gde je korupcija na visokom nivou, a pravda se može lako kupiti i prodati, ukupna sposobnost organa za provođenje zakona i pravosudnog sistema da podrže vladavinu prava je duboko potkopana. Međutim, korupcija je samo jedan od

negativnih faktora koji osporavaju inicijativu za vladavinu prava u zemljama Zapadnog Balkana. Ono što je najvažnije, postoji veoma malo političke volje, kako za borbu protiv ove korupcije, tako i za jačanje vladavine prava u cjelini (Kmezić, 2020).

VLADAVINA PRAVA U POLUAUTOKRATSKIM SISTEMIMA U ZEMLJAMA ZAPADNOG BALKANA

Vlade zemalja na Zapadnom Balkanu se mogu opisati kao „stabilokratije“, a njihovi lideri se mogu shvatiti kao autokrate koji zarobljavaju državu i tvrde da obezbjeđuju stabilnost u regionu Zapadnog Balkana, dodjeljujući sebi najveće zasluge na polju evropskih integracija (Staletović, & Bieber, 2024). Međutim, lideri ovih vlada se oslanjaju na neformalne, klijentelističke strukture, kontrolišu medije i redovno proizvode vještačke političke krize, kako bi potkopali sve istinske napore u jačanju vladavine prava (Cvetičanin, Bliznakovski, & Krstić, 2024; Radeljić, & Đorđević, 2020). U većini zemalja Zapadnog Balkana, autokrate su na vlasti, pa samo mali broj ljudi kontroliše ekonomiju i raspodjelu političke vlasti (Staletović, & Bieber, 2024). U takvom okruženju, podjela vlasti između sudske, izvršne i zakonodavne slabi u kontinuitetu i gotovo da dolazi do tačke nepostojanja. Politički lideri na vlasti imaju skoro apsolutnu kontrolu nad poslovima u zemlji, pa je u takvom okruženju prostor za jačanje vladavine prava i/ili razotkrivanje mreža organizovanog kriminala i korupcije daleko izazovniji. Do sada su u zemljama Zapadnog Balkana političke elite često jednostavno izbegavale krivično gonjenje, kao što je bio slučaj sa bivšim premijerom Sjeverne Makedonije, Nikolom Gruevskim, koji je prebačen u Mađarsku u danima kada je trebalo da bude zatvoren pod optužbom za zloupotrebu položaja i korupciju. Uprkos uslovima EU o suzbijanju korupcije i osiguranju da institucije, sa naglaskom na pravosudni sistem, budu slobodne od političkog uticaja, gotovo sve vlade u zemljama Zapadnog Balkana nisu pokazale nikakvu istinsku političku volju da ojačaju vladavinu prava (Muharemović, 2023). Političke elite imaju prekomjernu moć, a postoje veoma ograničeni mehanizmi koji bi mogli da ih pozovu na odgovornost. Jačanje vladavine prava je očigledno u suprotnosti sa interesima autokrata na vlasti, zbog čega je mnogo manje vjerovatno da bi takvo jačanje moglo uspjeti. U okruženju u kom javne institucije ne mogu u potpunosti da zaštite vladavinu prava zbog zarobljavanja države od strane autokratskih lidera, imperativ je da akteri civilnog društva, kao što su novinari, akademski građani, nevladine i druge organizacije, igraju važniju ulogu u preispitivanju reformi vezanih za ostvarivanje vladavine prava na putu ka EU integracijama (Hierlemann, et al., 2022).

ZAKLJUČCI

Najnovija dešavanja u politici proširenja EU su pokazatelj da je nakon Bregzita, EU željela da oživi svoj projekat proširenja, prvenstveno širenjem na Zapadni Balkan. Usmjeravanjem pregovora na područja od zajedničkog interesa, odnosno šest vodećih inicijativa iz Strategije EU - Zapadni Balkan 2018. može se smatrati dokazom obnovljenih političkih namjera EU da podrži zemlje Zapadnog Balkana u rješavanju i ostvarivanju održivog napretka po svojim unutrašnjim društveno-ekonomskim pitanjima. Primjenom inicijativa za jačanje vladavine prava na koju je stavljen fokus kada su u pitanju zemlje Zapadnog Balkana mogao se postići napredak u smanjenju korupcijskih uticaja na pravosudne sisteme ovih zemalja i njegovo usklađivanje sa standardima najbolje prakse u EU. Međutim, jačanje vladavine prava na papiru, donošenjem bilo kakvih formalnih paketa reforme pravosuđa nije bilo dovoljno da se u praksi ojača i održi vladavina prava. Inicijativa za vladavinu prava u zemljama Zapadnog Balkana predstavljala je mogući optimističan pristup Evropske komisije i imala potencijal da stvori produktivniju platformu za konstruktivan dijalog između EU i zemalja Zapadnog Balkana, odnosno da se uključe u politički dijalog zasnovan na dokazima. U zemljama Zapadnog Balkana neophodno je insistirati na izgradnji institucionalnih kapaciteta i na ulaganju u pravosudnu infrastrukturu, kako bi ona bila dostupnija građanima. U nedostatku nezavisnih institucija i uslovima zarobljene

države, formalno uključivanje članova civilnog društva u izradu nacionalnih akcionih planova za reformu vladavine prava u zemljama Zapadnog Balkana može pomoći svim faktorima uključenim u ove procese u istinskom provođenju reformi povezanih sa vladavinom prava u skladu sa najboljim praksama EU.

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THE RULE OF LAW IN THE COUNTRIES OF THE WESTERN BALKANS AS A FOCUS OF THE ENLARGEMENT POLICY OF THE EUROPEAN UNION

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ABSTRACT

Back in 2018, the European Union adopted the Strategy of enlargement to the countries of the Western Balkans, which provided a potential time and reform framework for accession negotiations on the accession of these countries to the European Union. Strengthening the rule of law, the fight against corruption and organized crime are the cornerstones of accession negotiations and European integration processes for the countries of the Western Balkans. This paper provides an overview of the EU Strategy - Western Balkans from 2018, where the focus is on the initiative to strengthen the rule of law and the analysis of the situation in these countries from the point of view of the rule of law.

Keywords: enlargement policy, EU, rule of law, corruption, organized crime, Western Balkans.

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GUIDELINES TO AUTHORS FOR WRITING PAPERS

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ABSTRACT

Guidelines to the authors on the manner of preparation of the article are designed in accordance with the best world publishing practice and the Rulebook on publishing scientific publications (Official Gazette of the Republic of Srpska, No. 77/17). The instruction was created in order to unify the style of publishing articles in all issues and editions of the scientific magazine "STED JOURNAL". The magazine is published semi-annually (May-November) in printed versions, with a circulation of 200 copies, and the electronic version of the issue is published at https://stedj-univerzitetpim.com/. All articles must be formatted in accordance with this Instruction and delivered to the email address of the journal. Each paper undergoes a preliminary elimination review, after which it is rejected or referred to the blind review process by two independent reviewers. Papers that have at least two positive reviews are published in the journal. The list of reviewers is adopted by the Editorial Board of the journal. The identity of the reviewer is not revealed to the authors and vice versa.

Keywords: STED Journal, review, publication, scientific publications

GUIDELINES TO AUTHORS FOR WRITING PAPERS

The guidelines to authors consist of two parts. The first part is related to the content aspect of the paper, that is, its necessary basic elements, based on which the reviewers evaluate the content adequacy of the paper. The second part of the guidelines is related to the technical aspect of formatting the paper based on which the editorial board, after receiving the paper, decides whether to send the paper to be reviewed or return it to the author to be finished before reviewing.

STED JOURNAL, the journal of the University PIM on social and technological development publishes the papers which are subject to review and which are classified into the following categories:

- Original scientific article,
- Review scientific article,
- Short or preliminary communication,
- Scientific critique,
- Professional article.

Authors suggest the category of their papers, but the final decision is made by the Editorial Board and reviewers.

Original scientific paper is a paper which is basically organised according to the IMRAD scheme (Introduction, Methods, Results and Discussion) for experimental research or in a descriptive way for descriptive scientific fields, in which one for the first time publishes the text on results of their own research carried out applying the scientific methods, which are described textually and which enable that the research is repeated in case of need, and the established facts are checked.

Review scientific article represents a review of the latest papers of a certain subject field, with the aim to summarise, analyse, synthesise and evaluate the information already published,

and moreover it brings new syntheses which also necessarily include the results of the author's own research.

Short or preliminary communication is an original scientific paper, but of a less extent or preliminary character, in which some elements of the IMRAD can be omitted, and it is about summarised presenting the results of a finished original research paper or article which is still in development (Working Paper).

Scientific critique, that is, a polemic or overview is a discussion to a certain scientific topic based specifically on scientific argumentation, in which the author proves the correctness of a certain criterion of their opinion, that is, they confirm or reject other authors' findings.

Professional paper is a contribution in which experience useful for improving the professional practice is offered, but which is not necessarily based on a scientific method, that is, the emphasis is on the usability of the results of original research and on spreading knowledge, and the text has to be adjusted to the professional and scientific level of the professional community for who the paper is intended.

The papers classified into these categories are subject to review by two reviewers. Reviews are double-blind, the authors' identity is not revealed to the reviewers and vice versa. The paper shall be published only based on positive reviews about which the Editorial Board shall inform the author. The reviewers are selected among experts in the direct field of research to which the paper submitted for publication is related.

The STED JOURNAL can include contributions from conferences, congresses, consultations and symposia.

The author is fully responsible for the content of the paper. The Editorial Board assumes that before submitting the paper the authors regulated the issue of publishing the content of the paper pursuant to the rules of the institution or company where they work.

The speed of publishing the paper will depend on how much the manuscript (text) complies with the guidelines. The papers requiring major modifications and amendments shall be returned to the author to be revised before reviewing.

TECHNICAL GUIDELINES

The paper shall be sent to the Editorial Board of the journal by e-mail in the form of a text prepared specifically using the text processing program of Microsoft Word.

The paper should consist of the following elements in English:

- Title of the paper;
- List of the authors and institutions;
- Abstract;
- Key words;
- Introduction;
- Theoretical framework;
- Experimental part;
- Results and discussion;
- Conclusion;
- Literature overview.

The title of the paper should be centred and written in upper case, Times New Roman, 14 pt, bold, Caps Lock;

The authors should be written in the centre, without titles, Times New Roman, 12pt, normal, and the names of institutions centred, Times New Roman, 10 pt, normal.

The titles of a part of the paper– of the first level, left alignment, Times New Roman, normal, 12 pt, bold, Caps Lock;

The subheading – of the second level, left alignment, lower case, Times New Roman, 12 pt, bold;

The subheading – of the third level, left alignment, lower case, Times New Roman, 12 pt, *italic*.

Other parts of the paper should be written using the alignment on both sides (Times New Roman, 12 pt), one-sided spacing with one empty row above, between the subheadings and paragraphs, with margins of 2.54 cm (1"). The beginning of the paragraph should be typed at the beginning of the row.

The abstract should have 100-250 words, and it is positioned between the paper heading (consisting of the paper title and information on authors) and key words, which are followed by the text of the paper.

If the paper is written in one of the official languages of Bosnia and Herzegovina, the summary in English is given in an extended form, as a so-called resume and it should consist of up to 500 words.

Tables and charts

Tables should be prepared in the WORD, graphics in the EXCEL, except for some special cases when it is not possible technically. Tables and graphics should be clear, as simple as possible and transparent. The title, heading (text) and subtext in tables and graphics should be written in Times New Roman – normal, Font Size 10 pt. Tables should be placed at a certain place in the text. Tables should not include more than ten columns and more than fifteen rows. If the author assumes that data should be presented in a larger number of columns and rows, it is necessary to split the content of the table into two or more smaller tables or deliver it as a special attachment. They have to be drawn according to the computer template (Insert Table), and not using the spacing, dots and tabs. When citing tables and graphics, we write the title of the table or graphic in the initial capital letter and then we specify its ordinal number (e.g. as it is shown in Table 9 and Figure 6, the lowest value was...).

A table example:

Table 1 The curing data for NR/CSM rubber blend compounds with different content of waste rubber powder

WRP content (phr)	Curing characteristics					
	M_l, dNm	M_h, dNm	ΔM, dNm	t_{s2}, min	t_{c90}, min	*CRI*
0	4	40	36	6	15	11.0
20	5	42	37	8	16	12.5
40	5	45	40	9	16	14.3
60	7	46	39	9	17	12.5
80	7	47	40	10	17	14.3
100	7	47	40	10	17	14.3

A chart example:

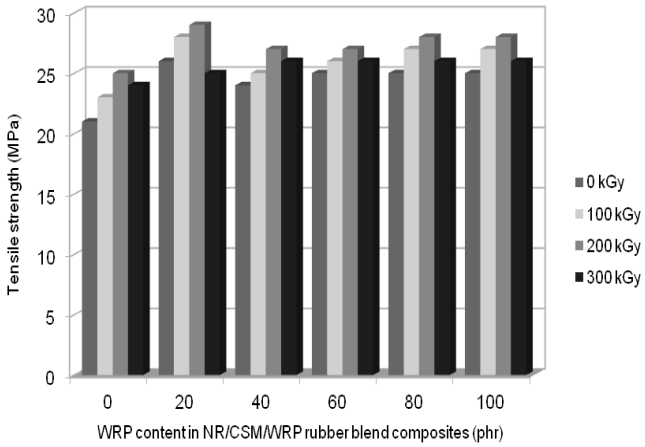

Figure 1 The effect of waste rubber powder content on tensile strength for the NR/CSM/WRP composites irradiated with different doses.

Equation

Equations should be written in the graphic editor for equations, specifically in the Microsoft Equation and they should be placed at the beginning of the text. On the right edge of the text in the row in which the equation is written one should indicate its number in parentheses beginning with number 1.

$$m_r = m_s\left(1 - e^{k_s t_{maks}}\right) - m_d\left(1 - e^{-k_d (t - t_{maks})}\right) \; za \quad t > t_{maks} \qquad (1)$$

Figures

Figures have to be prepared for black-and-white printing, that is, if the original figure is in colors which cannot be distinguished in black-and-white printing, the colors have to be replaced by "raster", that is, different graphic signs which need to be explained in the legend. We insert in figures only the most essential text necessary for understanding, such as measure variables with their dimensions, short explanation on curves and similar. The rest is stated in the legend under the figure (Figure 2). The maximum size of a figure is 13 cm x 17 cm.

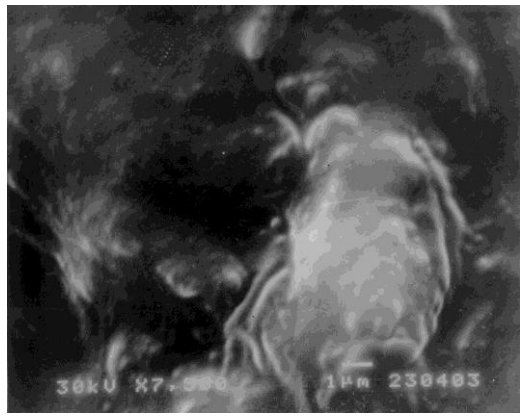

Figure 2 The SEM micrograph of NR/CSM/WRP composites filled with 20 phr waste rubber powder at 7500X magnification.

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Other notes

In order to include successfully the papers published in one of the official languages of Bosnia and Herzegovina into international information flows, parts of the manuscript should be written both in the author's language and in English, including: text in tables, figures, diagrams and drawings, their titles and symbols.

About authors

When sending the paper one should give their full official address, telephone number and e-mail of all authors and emphasize the author with who the Editorial Board shall cooperate. These notifications should be submitted on a separate sheet.

Experimental technique, symbols and units

Experimental techniques and devices are described in detail only if they deviate significantly from the descriptions already published in the literature. If techniques and devices are familiar, only the source of necessary notifications is stated.

Symbols of the physical quantities should be written in Italic (Times New Roman, 12 pt. – italic), and units of measurement in upright letters, e.g. *V, m, p, t, T*, but m^3, kg, Pa, °C, K. Quantities and units of measurement have to be used pursuant to the International System of Units (SI).

LITERATURE

The reference list at the end of the article has to include only the sources which the author referred to in the article text. The used literature items are listed in alphabetical order. Left 0", Right 0", Hanging 0.3", Before 0", After 0", Single. Primarily use journal references (minimum 50%, preferably more than 80%).

Examples of citing

An example of citing a scientific journal

The general form for citing papers from the journal is as follows: author's surname [comma], initial of first name(s) [dot], [open small bracket] year of publication [closed small bracket] [dot] title of the paper [dot], journal title - italic [comma] volume number - italic [open parenthesis] issue number [closed parenthesis] [comma] start page [dash] end page [dot].

In the text:

When the author(s) are mentioned in the sentence and his/her words are stated, then after the author's name the year of publication of the cited work and the page number in brackets are stated:

- one author: (Avramović, 2011);
- two authors: (Žiravac-Mladenović i Đurica, 2018);
- three to five authors: first citing in text: (Mitić, Nikolić, Cakić, Nikolić, & Ilić, 2007); second and every next citing in text: (Mitić et al., 2007);
- six and more authors: (Špírková et al., 2009).

In the reference list:

Avramović, D. (2011). Metode i okviri rasta vrijednosti banke. *Anali poslovne ekonomije, 5*(1), 28-37.

Žiravac-Mladenović, M. i Đurica, F. (2018). Komparativna analiza trgovanja na Banjalučkoj i Sarajevskoj berzi. *Anali poslovne ekonomije, 10*(1), 25-35.

Mitić, Ž., Nikolić, G., Cakić, M, Nikolić, R., & Ilić, LJ. (2007). The investigation of Co (II)-dextran complexes. *Hemijska industrija, 61*(5), 257-262.

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Špírková, M., Strachota, A., Urbanová, M., Baldrian, J., Brus, J., Šlouf, M., Kuta, A. & Hrdlička, Z. (2009). Structural and surface properties of novel polyurethane films. *Materials and Manufacturing Processes, 24*(10-11), 1185-1189.

An example of citing a book in the text:

- one author: (Suzić, 2010);
- two authors: (Peterlin i Mladenović, 2007);
- three to five authors: first citing in text: (Đuranović, Todorović i Tešić 2016); second and every next citing in text: (Đuranović et al., 2016);
- six and more authors: (Stefanović et al., 2008).

In the reference list:

Suzić, N. (2010). *Prvila pisanja naučnog rada: APA i drugi standardi.* Banja Luka: XBS.

Peterlin, J. i Mladenović, M. (2007). *Finansijski instrumenti i menadžment finansijskih rizika.* Banja Luka: Univerzitet za poslovni inženjering i menadžment.

Đuranović, D., Todorović, S. i Tešić, R. (2016). *Strategijski menadžment.* Banja Luka: Univerzitet za poslovni inženjering i menadžment.

Stefanović et al. (2008). *Kretanje šinskih vozila.* Banja Luka: Društvo za energetsku efikasnost.

An example of citing a chapter of a book in the text:

- (Harly, 1981)

In the reference list:

Harley, N. (1981). Radon risk models. U A. Knight, & B. Harrad (Eds.), *Indoor air and human health* (str. 69–78). Amsterdam: Elsevier.

An example of citing a paper published in the Scientific Conference Proceedings in the text:

- one author: (Grgurević, 2014);
- two authors: (Medić i Živadinović, 2014);
- three to five authors: first citing in text: (Krstić, Skorup, Skorup, 2014); second and every next citing in text: (Krstić et al., 2014);
- six and more authors: (Kojić et al., 2019).

In the reference list:

Grgurević, N. (2014). Kuba i Nikaragva (Revolucija i postrevolucionarni period). U M. Žiravac-Mladenović (Eds.), *Conference proceedings, International Scientific Conference on Social and Technological Development* (pp. 124-131). Banja Luka, B&H: University of Business Engineering and Management.

Medić, Z. i Živadinović, J. (2014). Neravnoteže i krize savremenog doba i ekonoska politika. U M. Žiravac-Mladenović (Eds.), *Conference proceedings, International Scientific Conference on Social and Technological Development* (pp. 102-1112). Banja Luka, B&H: University of Business Engineering and Management.

Krstić, M., Skorup, A. i Skorup, S. (2014). Inovativnost – ključni element preduzetničke strategije rasta i razvoja privrednog subjekta. In Žiravac-Mladenović, M. (Eds.), *Conference proceedings, International Scientific Conference on Social and Technological Development* (pp. 51-58). Banja Luka, B&H: University of Business Engineering and Management.

Kojić, D., Pavličević, J., Špírková, M., Aroguz, A., Jovičić, M., Bera, O., MarinovićCincović, M. (2019). THE IFLUENCE OF SILICA ON THE SOLVENT RESISTANCE OF POLYURETHANE HYBRIDE MATERIALS. In Gligorić, M., Došić, A. i Vujadinović, D. (Eds.), *Proceedings VI International Congress "Engineering, Environment and Materials in Processing Industry"* (pp. 568-572). Jahorina, BiH: University of East Sarajevo, Faculty of Technology.

Kojic, D., Žiravac Mladenović, M. & Pavlicevic, J. (2024). Guidelines authors for writing papers. *STED Journal, 6*(2), 93-99.

An example of citing a master thesis or PhD thesis in the text:

- (Petrović, 2001)
- (Žiravac-Mladenović, 2009)

In the reference list:

Petrović, R. (2001). *Dehidratacija etera na mordenitnim katalizatorima.* Magistarski rad. Univerzitet u Banjoj Luci, Tehnološki fakultet, Banja Luka, BiH.

Žiravac-Mladenović M. (2009). *Bankarski nadzor i regulative zemalja u tranziciji na Balkanu – globalizacija bankarskog sektora.* Alfa Univerzitet, Beograd, Srbija.

An example of citing a publication of an institution as the author, downloaded from the Internet and citing a text from the web site

Citing internet sites should be avoided, but if it is necessary, then they should include names of the authors, if they are available, the title, internet site and access date.

In the text:

- institution: first citing in text (Zavod za statistiku Republike Srpske [ZSRS], 2009); second and every next citing (ZSRS, 2009);
- call to authors: (Degelman, 2000); - unknown author: (Compiere, 2017) (Purdue University, n.d)

In the reference list:

Zavod za statistiku Republike Srpske. (2009). Saopštenja. Preuzeto 10.02.2009. sa http://www.rzs.rs.ba/SaopstenjaRadLAT.htm

Degelman, D. (2000). APA Style Essentials. Retrieved May 18, 2000 from: http://www.vanguard.edu/psychology/apa.pdf

Compiere, (2017). Products. Preuzeto 11.10.2018. sa http://www.compiere.com/products/

Purdue University Writing Lab [Facebook page]. (n.d). Retrieved January 22, 2019, from https://www.facebook.com/PurdueUniversityWritingLab/

An example of citing laws, regulations, court decisions in text:

- laws and regulations: first citing in text (Zakon o krivičnom postupku [ZKP], 2014); second and every next citing (ZKP, 2014);
- court decisions: first citing in text (Vrhovni sud Srbije [VSS], Rev. 1354/06); second and every next citing (VSS, Rev. 1354/06);

In the reference list:

Zakonik o krivičnom postupku, Službeni glasnik RS, 72/2011, 101/2011, 121/2012, 32/2013, 45/2013, i 55/2014; Regulation (EU) No. 1052/2013 establishing the European Border Surveillance System (Eurosur), OJ L 295 of 6/11/2013, 1; Directive 2013/32/EU on common procedures for granting and withdrawing international protection (recast), OJ L 180 of 29/6/2013, 60.

Vrhovni sud Srbije, Rev. 1354/06, (6. 9. 2006). Paragraf Lex; Vrhovni sud Srbije, Rev. 2331/96, 3. 7. 1996, Bilten sudske prakse Vrhovnog suda Srbije 4/96, 27; CJEU, case C-20/12, Giersch and Others, ECLI:EU:C:2013:411, para. 16; Opinion of AG Mengozzi to CJEU, case C-20/12, Giersch and Others, ECLI:EU:C:2013:411, para. 16.

CONCLUSION

Papers not written strictly according to these guidelines shall not be accepted.

Cooperative Online Bibliographic System and Service COBISS Standard ISO 690

STED journal : journal of social and technological development Vol. 6, No. 1 (2024)

1. JOKSIMOVIĆ, Nenad, PETRONIJEVIĆ, Jelena, SERAFINOVIĆ, Marina, JANKOVIĆ, Nenad, BASKIC, Dejan. Anticancer Potential of Novel palladium(II) Comlexes with Acyl Pyruvates as Ligands : DNA and BSA Interactions and Molecular Docking Study. *STED journal : journal of social and technological development*. [Štampano izd.]. 2024, vol. 6, no. 1, pp. 1-14. ISSN 2637-2150. http://dx.doi.org/10.7251/STED2401001J. [COBISS.RS-ID 140644097]

2. LATINOVIĆ, Boris, OSTOJIĆ, Bojana, ILIĆ, Biljana, PEĆIĆ, Milutin, ČABARKAPA, Obrad. Marketing Strategies in Recruiting and Training Volunteers for the Organization of Sports Competitions. *STED journal : journal of social and technological development*. [Štampano izd.]. 2024, vol. 6, no. 1, pp. 24-33. ISSN 2637-2150. http://dx.doi.org/10.7251/STED2401024L. [COBISS.RS-ID 140645377]

3. LOLIĆ, Slađana. Problemska nastava matematike. *STED journal : journal of social and technological development*. [Štampano izd.]. 2024, vol. 6, no. 1, pp. 73-78. ISSN 2637-2150. http://dx.doi.org/10.7251/STED2401073L. [COBISS.RS-ID 140643841]

4. MILOVANOVIĆ, Mirjana, DUŠANIĆ-GAČIĆ, Svetlana. Analysis of Economic and Bsiness Indicators of Entrepreneurship in Republic of Srpska. *STED journal : journal of social and technological development*. [Štampano izd.]. 2024, vol. 6, no. 1, pp. 15-23. ISSN 2637-2150. http://dx.doi.org/10.7251/STED2401015M. [COBISS.RS-ID 140644353]

5. NOVAKOVIĆ, Nikola, RADIVOJEVIĆ, Davor. Blockchain u javnoj upravi Bosne i Hercegovine. *STED journal : journal of social and technological development*. [Štampano izd.]. 2024, vol. 6, no. 1, pp. 46-55. ISSN 2637-2150. http://dx.doi.org/. [COBISS.RS-ID 140644609]

6. VASELIĆ, Darko, JANJETOVIĆ, Ljubica. Stavovi korisnika digitalnih tehnologija o njihovom uticaju na svakodnevni život, posao i mentalno zdravlje. *STED journal : journal of social and technological development*. [Štampano izd.]. 2024, vol. 6, no. 1, pp. 56-72. ISSN 2637-2150. http://dx.doi.org/10.7251/STED2401056V. [COBISS.RS-ID 140644865]

7. VASELIĆ, Darko, VOJVODIĆ, Nikola, JOVOVIĆ, Jelena. Vještačka inteligencija : efekti na društvo i ekonomiju i njeno regulisanje. *STED journal : journal of social and technological development*. [Štampano izd.]. 2024, vol. 6, no. 1, pp. 34-45. ISSN 2637-2150. http://dx.doi.org/10.7251/STED2401034V. [COBISS.RS-ID 140645121]

Registar naslova

Registar autora

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- Serafinović, Marina (autor) 1

- Vaselić, Darko (autor) 6
- Vaselić, Darko (autor) 7
- Vojvodić, Nikola (autor) 7

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