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TABLE OF CONTENTS

Data Modelling of Physical-Mechanical Processes in Nano Concrete with the Ensemble of Pores

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Abstract. This paper assesses the strength of nano concrete and methods of strengthening it by adding nanoparticles. Since concrete structures are exposed to the environment and external influences, there is a need to enhance resistance to destruction. Modelling of behaviour and the nature of changes in indicators of chemical shrinkage and destructive load is performed. Data analysis is executed based on the data of ordinary portland cement pastes and cement-fly ash pastes. The results are compared with admixtures to these materials of three nanomaterials: nanolimestone, nanosilica, and nanoclay. The percentage ratio for compressive strength for materials is established. The data processing and visualization of the results are presented using an interactive web page using dynamic mathematical calculations of approximation and interpolation based on the entered data. The data is processed using modern open-source libraries and stored in the database. The work aims to develop a methodological approach for modelling physico-mechanical processes in nano concrete, considering nanoparticles and an ensemble of pores.

Keywords: nanomaterial; compressive strength; computer modelling.

INTRODUCTION

One of the primary materials in construction is concrete based on sand-cement mixtures. This material must withstand heavy loads and be stable under various weather conditions, so the compressive strength parameter can be considered an additional factor in improving the stability of concrete structures [1, 2].

Forecasting the strength and durability of nano concrete is expedient to assess the levels of reliability and resource using optimisation methods. Fundamental processes in this context relate to mechanical loads and the pore medium. It is possible to simulate the penetration of the pore fluid into the solid-phase frame and the redistribution (filtration) of the fluid in the pore space of the material. The porous medium is characterised by integral parameters, such as the volume of the pore space, porosity and permeability [3, 4, 5]. The liquid (water) in the porous medium of nano concrete is considered implicitly and is also characterised by integral parameters: mass, density, pressure, and dynamic viscosity [3, 4].

The work aims to model such physical and mechanical processes as compressive strength, water and calcium hydroxide content in nano concrete, considering nanoparticles and the ensemble of pores.

One of the tasks of this work is the development of a strength criterion for nano concrete, taking into account the ensemble of pores based on the approaches of surface physics and fracture mechanics. In addition, the evaluation of the quality of nano concrete, taking into account the physical and mechanical characteristics of the rigid frame and porous medium, is taken into account.

Another task is the formulation of criterion ratios based on evaluating the strength, reliability,

strengthening parameter and residual resource of nano concrete, and taking into account the porous medium.

MATERIAL AND METHODS

The non-associated law of plastic flow with the Mises-Schleicher criterion is used to describe stress relaxation and accumulation of inelastic deformation in nano concrete, which is used to model the behaviour of brittle natural and artificial materials [5, 6]:

$$Y = \alpha\sigma_{s(eff)} + \sigma_{\text{int}} / \sqrt{3} = \alpha\left(\sigma_s + P_{pr}\right) + \sigma_{\text{int}} / \sqrt{3}, \quad (1)$$

where Y – adhesion characteristic (elastic limit of the material in pure shear); σ_{int} – stress intensity; α – coefficient of internal friction; $\sigma_{s(eff)}$ – average effective stress; P_{pr} – actual pressure value in the pore medium of the element.

The main defining relations connecting the averaged stresses and deformations of the solid-phase frame of the element, as well as the fluid pressure in the pore (capillary) space of the element, are of the form [5, 6]:

$$\Delta\sigma_{\alpha\beta} = 2G(\Delta\varepsilon_{\alpha\beta} - \delta_{\alpha\beta}a\Delta P_{pr} / K) + \delta_{\alpha\beta}(1 - 2G / K)\Delta\sigma_s,$$

$$\delta V = \delta\varphi = \frac{a}{K}\Delta\sigma_s + \left(\frac{1}{K} - \frac{1+\varphi}{K_s}\right)\Delta P_{pr}, \quad (2)$$

$$\delta P_{pr} = K_L\left(\frac{\rho_L}{\rho_{L0}} - 1\right) = K_L\left(\frac{m_L}{\rho_{L0}V_p} - 1\right), \quad (3)$$

where $\delta\varphi=\varphi-\varphi_0$; $\delta V=(V_p - V_{p0})/V$; $\varphi=V_p/V$; $\varphi_0=V_{p0}/V$; σ_s – average tension; φ, φ_0 – current and initial value of porosity; Δ – the symbol of the increase of the corresponding variable per time step during the integration scheme of the equations of motion of the element of the continuous medium of nano concrete; $\varepsilon_{\alpha\beta}$, $\sigma_{\alpha\beta}$ – components of tensors of averaged strains and stresses in the volume element; G and K – shear modulus and all-round compression modulus of the element material in the absence of pore fluid (mixture); $\delta_{\alpha\beta}$ – Kronecker symbols; $a = (1 - K/K_s)$ – coefficient of porosity in the Biot model [6, 7]; K_s – module of comprehensive compression of the material of the frame walls.

V_p, V_{p0} – current and initial volume (in the undeformed element); V is the volume of the component; ρ_{L0}, P_{pr0}, – the equilibrium value of the density and pressure of the liquid under atmospheric conditions (in the absence of a mechanical limitation of the volume of the liquid); ρ_L – current density value in the pore medium of the element; K_L – modulus of comprehensive liquid compression (mixtures).

As a criterion for the destruction of the frame and cement mixture, the Drucker-Prager criterion is used, which derives the expression for the effective Tercaghi stresses [5, 8, 9]:

$$\sigma_f = 1,5(\beta - 1)\sigma_{s(eff)} + 0,5(\beta + 1)\sigma_{\text{int}} = \sigma_c, \quad (4)$$

where $\beta = \sigma_c/\sigma_t$; σ_c and σ_t – the value of the compressive and tensile strength of the frame material. For nonporous basalt, the traditional formulation of the Drucker-Prager criterion is used, in which instead of $\sigma_{s(eff)}$ (4) is used σ_s [5, 8, 9].

The Griffiths-Irwin-Orovan strength criterion is also used [10]:

$$\sigma_* = \sqrt{\frac{4E \cdot WPL}{\pi \cdot L_T(1 - \nu^2)}}, \quad (5)$$

where σ_* – compressive strength; L_T – pore diameter; WPL – specific energy spent on plastic deformation of the near-surface (interfacial) layer of the body, provided that a new (juvenile) surface is formed in it; E, ν – Young's modulus and Poisson's ratio of the frame, respectively.

In reinforced concrete, rust forms on the surface of the reinforcement. Corrosion products (in particular, rust) penetrate the pores. Parameter WPL is included in the expression I_a corrosion current [11]:

$$I_a = I_{as}(1 + \beta_w \cdot WPL) = \chi \cdot \Delta\psi_{ak}(1 + \beta_w \cdot WPL) / r, \quad (6)$$

where χ – electrical conductivity of the electrolyte; $\Delta\psi_{ak}$ – ohmic potential change between the anodic and cathodic parts (anode – top, cathode – edges of the crack (pores)); r – pore radius; I_{as}, β_w – constants that are determined from the experiment.

Ratios (1)–(6) and the quality criterion [11] will be used to estimate the parameters of the stress-strained state and the conditions for strengthening nano concrete.

The reliability parameter β_R (reliability) (security characteristic) based on the probabilistic approach is determined by the ratio [11]:

$$\beta_R = Y_{RM} / Y_{SRM}, \quad (7)$$

where Y_{RM} – strength reserve; Y_{SRM} – strength reserve standard.

There is a transitional state between the rigid frame and the pore. The energy of adhesive bonds γ_{ad} and its change $\Delta\gamma_{ad}$ depend on the energy characteristics of the frame and the pore medium. Formulate the interphase ratio of the strength criterion between the frame and the pore medium similar to the coating, taking into account the results of the article [12, 13, 14, 15]:

$$\delta\sigma_m \le \delta\sigma_{m*}, \delta\gamma_m \le \delta\gamma_{m*}, \delta A_{ad} \le \delta A_{ad*},$$
$$\delta\gamma_{vad} \le \delta\gamma_{ad*}, \quad (8)$$

where $\delta\sigma_m$ – change in interfacial tension; $\delta\gamma_m$ – change of interfacial energy; δ – the symbol of deviation (change) of the parameter or energy characteristic of the interfacial layer; δA_{ad} – change in adhesion performance; $\delta\sigma_{m*}$, $\delta\gamma_{m*}$, δA_{ad*}, $\delta\gamma_{ad*}$ – empirical constants.

Similarly to the article [11], the qualitative criterion of quality for the structural element of nano concrete is given in the form of the ratio:

$$Z_1 = \beta_1 k_1 \cdot k_2 \cdot k_3 + \beta_2 \prod_{i=4}^{7} k_i, \quad (9)$$

where k_1 – the coefficient of the level of reliability of nano concrete; k_2 – the coefficient that characterises the level of strength of the rigid frame; k_3 – the coefficient that characterises the resource of the porous medium; $k_4(D_f)$, $k_5(n_Z)$, $k_6(\sigma_{ve})$, $k_7(K_S)$ – coefficients that characterise the defectiveness D_f, strengthening of the material n_Z, the limit of corrosion fatigue σ_{ve}, taking into account the corrosion resistance of fittings K_S; β_1, β_2 – empirical constants.

Ratios (1), (2), (4), (5), and (8) constitute a new version of the strength criterion for the system nano concrete frame – pore medium. The parameters of the expressions (1), (2), (4), and (5) can be determined based on the experiment, and the parameters of the ratios (8) are estimated based on the computational experiment.

Theory/calculation

The data processing process can be automated using computer programs. The most popular method of viewing information from anywhere is a web page. This way, users can perform calculations and visualise the results in real-time. Bootstrap and ChartJS libraries are used in this work, which is open source and free to use.

These libraries can dynamically configure graphic objects' display parameters and show real-time changes. When the user moves the mouse over the graph points, the digital representation helps the user see the current value. This simplifies data analysis and allows for the extension of the application. In addition, libraries with implemented mathematical algorithms can be used to model various processes, particularly for compressive strength. The data is stored in a database for constant data access and storage of intermediate calculation results. Figure 1 presents a visual view of the information processing results for various nanomaterials [1]. Thus, these results can dynamically change and add new ones as needed. To analyse a specific area, it is possible to increase the scale.

The top three graphs show the difference between the ordinary portland cement paste and three nanomaterials, nanolimestone (NL), nanosilica (NS), and nanoclay (NC). The second row of graphs shows the changes considering the cement-fly ash blended paste (OPCFA).

RESULTS AND DISCUSSION

As a result of data processing determined, the change in the compressive strength σ_* and water and calcium hydroxide content for cement paste after curing parameter when using different mixtures. Comparative graphic characteristics of the parameter change make it possible to estimate the difference in the strengthening of materials each time.

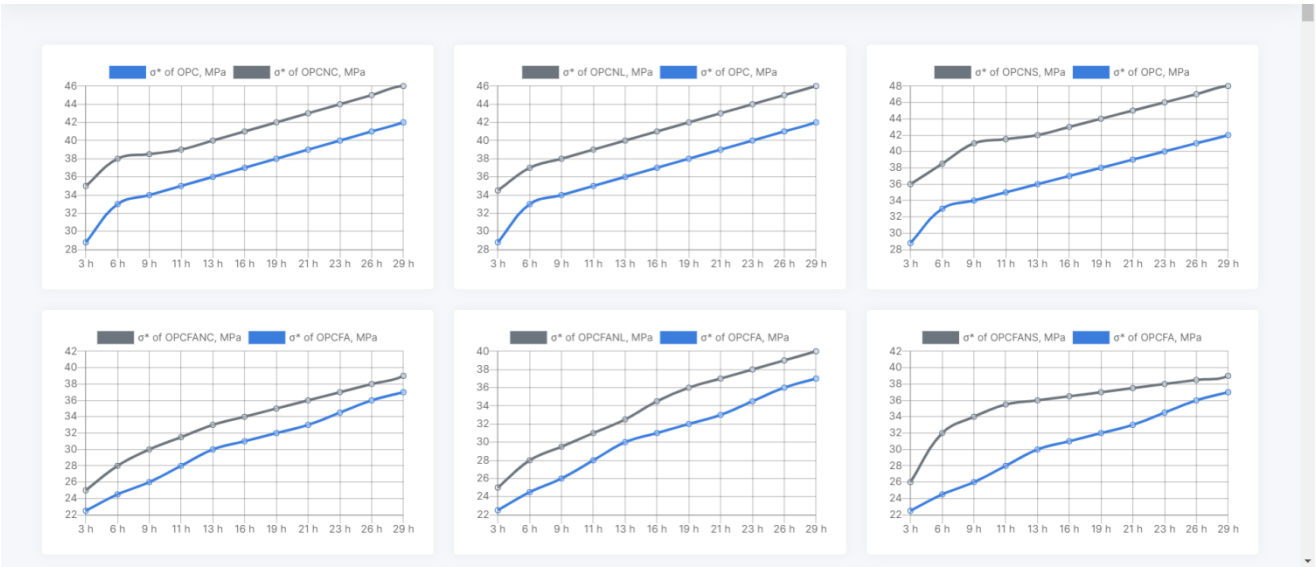
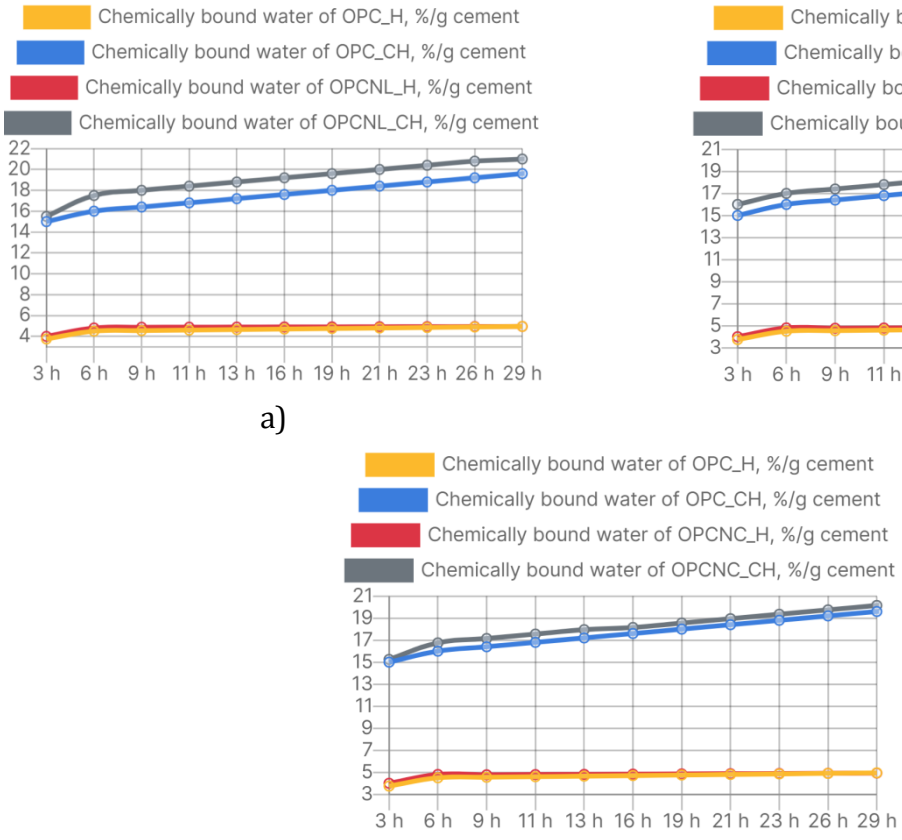
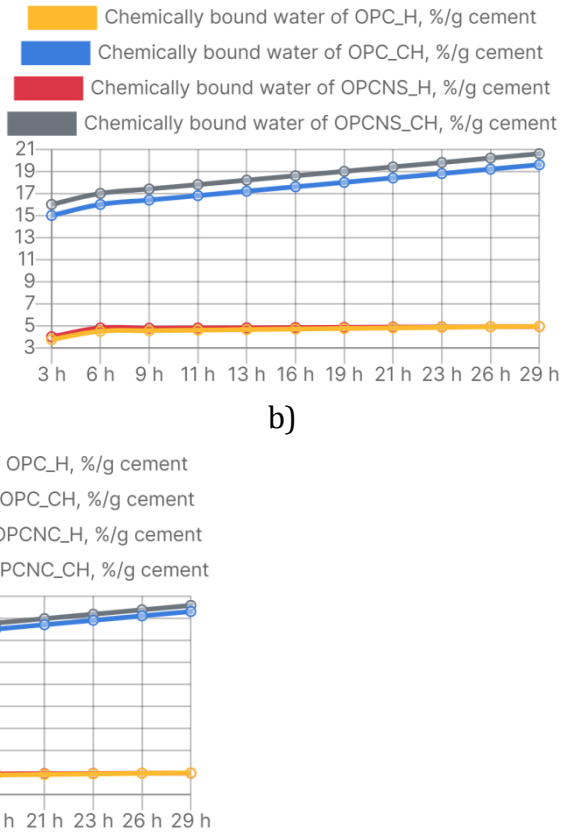


Figure 1 – An example of the results web page

Figure 2 shows the interpolation of water and calcium hydroxide data over time. The change of this parameter from 3 to 29 hours is shown. The upper graph shows the difference in the ordinary portland cement paste (OPC) with the addition of nanomaterials, such as the cement paste with additions of nanolimestone, nanosilica and nanoclay. Chemically bound water increases over time for all nanomaterials, according to the conducted experiment [3].



a)



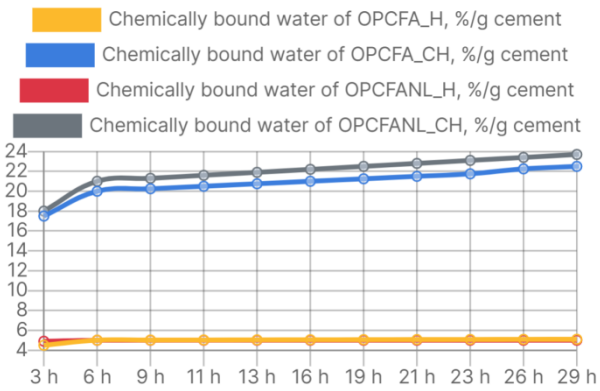
b)

c)

Figure 2 – Interpolation of water and calcium hydroxide content for cement paste after curing

Notes: a) the cement paste with nanolimestone (OPCNL); b) the cement paste with nanosilica (OPCNS); c) the cement paste with nanoclay (OPCNC)

Figure 3 shows the interpolation of these same materials considering the cement-fly ash blended paste (OPCFA). Such a mixture provides cohesion and filling of pores in the cement mixture, which is due to the lower indicators of chemically bound water compared to without the addition of this additive. The lower graph from the upper group of diagrams in this figure takes into account the cement-fly ash blended paste (OPCFA) and the upper ones with the addition of nanoparticles, respectively, in Figure 3a is the cement-fly ash paste with nanolimestone (OPCFANL), in Figure 3b – cement-fly ash paste with nanosilica (OPCFANS), 3c – cement-fly ash paste with nanoclay (OPCFANC). Moreover, the indicators with H shown in the lower group of graphs in Figures 2 and 3 practically do not change over time.



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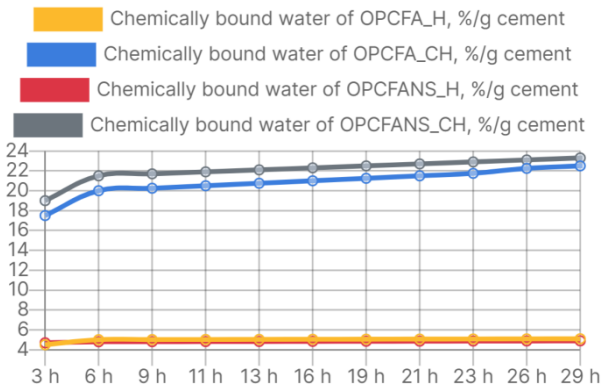
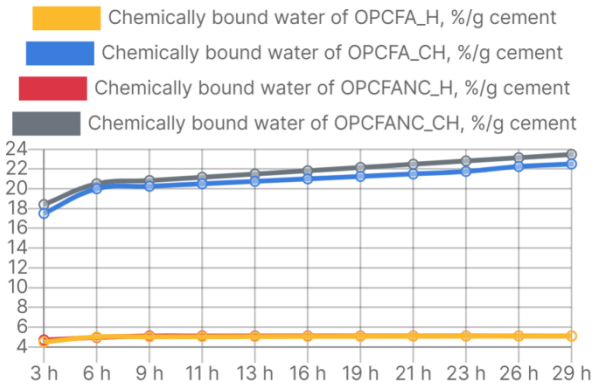


b)



c)

Figure 3 – Interpolation of the content of water and calcium hydroxide for cement-ash paste after curing

Notes: a) cement paste with the addition of nanolimestone (OPCFANL); b) cement paste with the addition of nanosilica (OPCFANS); c) cement paste with the addition of nanoclay (OPCFANC)

Figure 4 shows a linear approximation, which shows the linear nature of changes in this parameter. The percentage deviation from the linear approximation is 17.32% for the ordinary portland cement paste (OPC) is 11.62% with NS, 10.28% – NL, and 7.6% – NC. Among all nanoparticles, the compressive strength increases linearly in a cement mixture with nanoclay. The most significant difference is observed in the first points due to the use of a linear approximation.

Figure 5 shows the overlay of the linear approximation on changes in the compressive strength parameter. On these graphs, compared to the cement-ash mixture and nanoparticles, the percentage difference between the linearly approximated straight line and the compressive strength change graph: cement-fly ash paste (OPCFA), 41.4% – cement-fly ash paste with nanolimestone (OPCFANL) (Fig. 5a), 17.71% – cement-fly ash paste with nanosilica (OPCFANS) (Fig. 5b), 20.75% – cement-fly ash paste with nanoclay (OPCFANC) (Fig. 5c). It can be assumed that the square root function is more suitable for such materials.

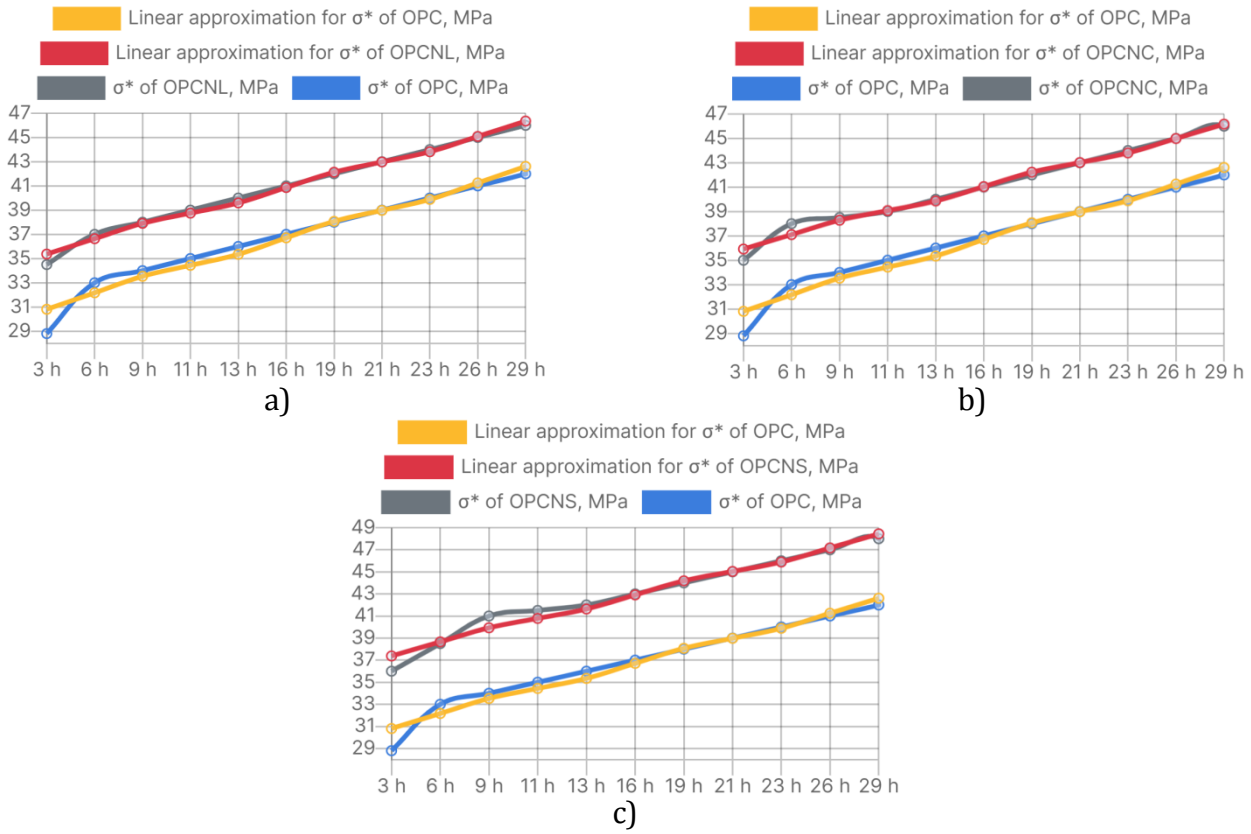


Figure 4 – Approximation of the compressive strength σ_* for cement paste with: a) cement paste with the addition of nanolimestone (OPCNL); b) cement paste with the addition of nanosilica (OPCFAS); c) cement paste with the addition of nanoclay (OPCNC)

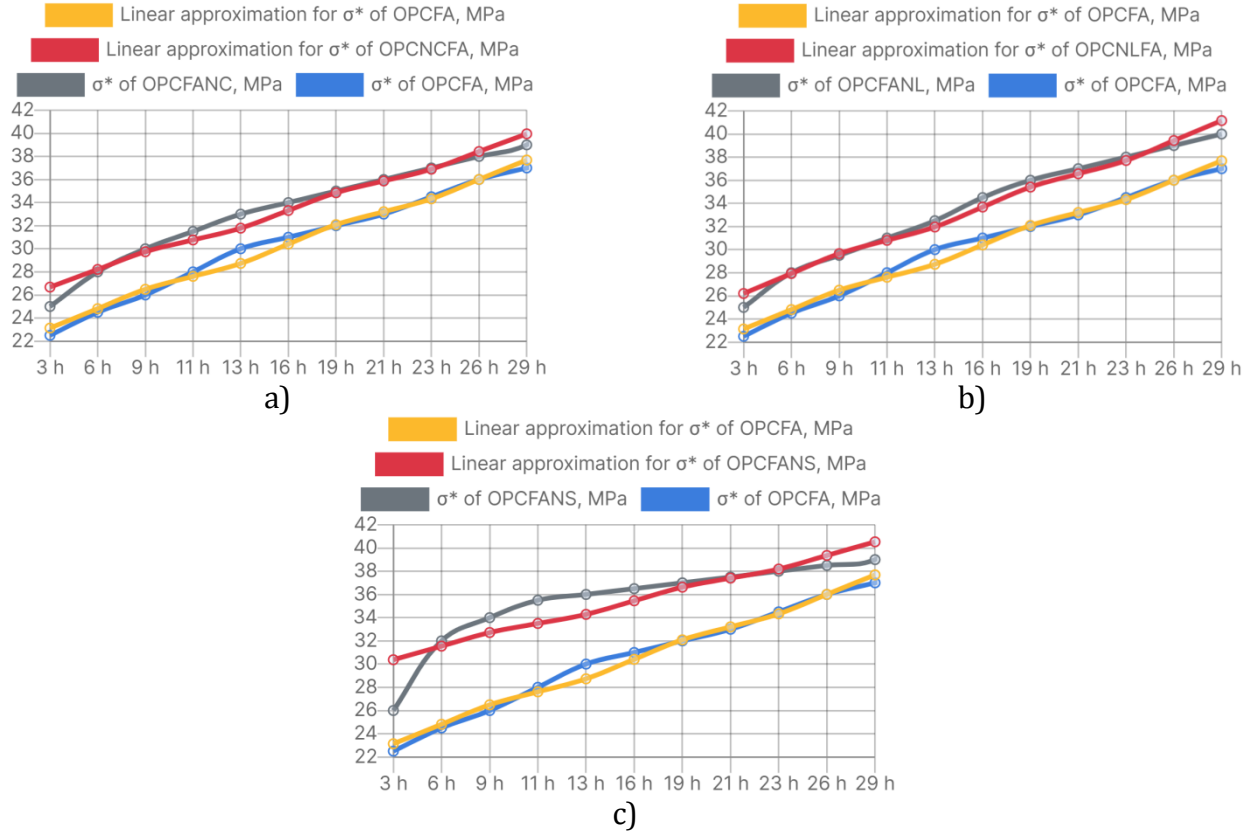


Figure 5 – Approximation of the compressive strength σ_* for cement-fly ash paste (OPCFA)

Notes: a) cement-fly ash paste with nanolimestone (OPCFANL); b) cement-fly ash paste with nanosilica (OPCFANS); c) cement-fly ash paste with nanoclay (OPCFANC)

Table 1 shows the percentage difference between the compressive strength of ordinary cement paste (OPC) and with the addition of nanomaterials of nano limestone (OPCNL), nanosilica (OPCNS) and nanoclay (OPCNC) over time-based on Figure 2a, 2b and 2c.

Table 1 – The percentage difference between the compressive strength σ_* of the ordinary cement mixture (OPC) and with the addition of the nanomaterials of nanolimestone (OPCNL), nanosilica (OPCNS), nanoclay (OPCNC) and cement-fly ash paste (OPCFA) and with the addition of the nanomaterials of nano-limestone (OPCFANL), nanosilica (OPCFANS), and nanoclay (OPCFANC) over time

Time, h	σ_* of OPCNL, %	σ_* of OPCNS, %	σ_* of OPCNC, %	σ_* of OPCFANL, %	σ_* of OPCFANS, %	σ_* of OPCFANC, %
3	13.51	13.95	9.75	10.14	15.07	8.82
6	19,79	20	17,71	10	13,46	10
9	13,15	13,63	9,52	11,11	13,51	8,57
11	12,82	13,33	9,3	10,81	12	8,33
13	12,12	14,28	13,15	12,5	23,43	12,5
16	12,5	13,04	9,09	9,21	9,21	6,76
19	13,23	17,07	11,7	11,86	23,52	13,33
21	12,19	12,76	8,88	7,69	6,49	5,26
23	14,28	15,66	10,25	9,68	21,13	11,11
26	13,89	14,28	10	7,69	16,67	9,09
29	11,9	12,5	8,69	7,5	5,12	5,12
Mean	13,51	16,975	9,875	10,07	18,05	9,41

As shown in Table 1, with the addition of nanoparticles, all materials have higher destructive load indicators and become stronger. The most significant average deviation from the usual mixture in strength with the addition of nanosilica to the cement mixture (OPCNS) and less with the addition of nanoclay (OPCNC). On average, when added to a conventional cement mixture, the addition of nanoparticles equals 13.45%.

With the addition of nanosilica (OPCFANS) to the cement-ash mixture, such a mixture becomes the strongest. Compared to the cement mixture with nanosilica, the same combination is still worse in terms of results since the values obtained for compressive strength in Figure 2 have higher values of compressive strength compared to those with the cement-ash mixture in Figure 3.

By selecting approximation, it is possible to summarise the characteristics of the change of these parameters. This mathematical analysis allows you to work out and analyse the results. Theoretical results can be simulated programmatically using the developed web page. Different pastes can be programmatically affected and compare theoretical results in this case.

Table 1 shows the percentage difference for different pastes with additives in each period. It can conclude the strength based on the compressive strength indicators. For cement and cement-ash pastes and with nanosilica, nanoclay and nanolimestone nanoparticles, data analysis is performed using linear interpolation and approximation methods to determine the nature of the compressive strength parameter.

Since the linear approximation is possible for deviation values that are not significant, it can be assumed that the strengthening coefficient increases linearly for cement paste and the behaviour of the square root function (branch of the parabola) for cement-ash pastes for a period from 3 hours to 29 hours. However, if it is considered that the beginning is from 1 hour, then in the first hours, this parameter increases the most and, in general, resembles the branch of a parabola.

Another parameter of strength can be considered the water and calcium hydroxide content after curing.

The paper also mathematically shows the influence of the destructive load parameter on changes in the quality of nano concrete, which can be used to assess strength and corrosion processes.

CONCLUSIONS

1. A new version of the nano concrete strength criterion is proposed, taking into account the en-

ergy characteristics of the interphase layers between the solid framework and the micropore medium, which characterise the connections (adhesion) of the two media.

2. The relationship between surface physics and fracture mechanics is the basis of the methodology for assessing the quality of nano concrete and can be used to determine the resource of the material and the strengthening parameter, taking into account the criteria of strength, corrosion processes and metrological support.

3. Based on the obtained results, the strength, reliability, strengthening parameter and residual resource of nano concrete can be evaluated, taking into account the porous medium.

4. With the help of software modelling using mathematical methods, it is possible to improve the structure, manipulate the number of nanomaterials, and determine the characteristics of nano concrete.

REFERENCES

1. Popova, N., Kataiev, A., Skrynkovskyy, R., & Nevertii, A. (2019). Development of trust marketing in the digital society. *Economic Annals-XXI, 176*(3–4), 13–25. doi: 10.21003/ea.v176-02
2. Popova, N., Kataiev, A., Nevertii, A., Kryvoruchko, O., & Skrynkovskyi, R. (2021). Marketing Aspects of Innovative Development of Business Organizations in the Sphere of Production, Trade, Transport, and Logistics in VUCA Conditions. *Studies of Applied Economics, 38*(4). doi: 10.25115/eea.v38i4.3962
3. Wang, X. (n.d.). *Effects of nanoparticles on the properties of cement-based materials*. doi: 10.31274/etd-180810-5865
4. Psakhie, S. G., Dimaki, A. V., Shilko, E. V., & Astafurov, S. V. (2015). A coupled discrete element-finite difference approach for modeling mechanical response of fluid-saturated porous materials. *International Journal for Numerical Methods in Engineering, 106*(8), 623–643. doi: 10.1002/nme.5134
5. Konovalenko, Ig. S., Shilko, E. V., & Konovalenko, Iv. S. (2020). The Numerical study of the influence of a two-scale pore structure on the dynamic strength of water-saturated concrete. *PNRPU Mechanics Bulletin, 2*, 37–51. doi: 10.15593/perm.mech/2020.2.04
6. Garavand, A., Stefanov, Y. P., Rebetsky, Y. L., Bakeev, R. A., & Myasnikov, A. V. (2020). Numerical modeling of plastic deformation and failure around a wellbore in compaction and dilation modes. *International Journal for Numerical and Analytical Methods in Geomechanics, 44*(6), 823–850. doi: 10.1002/nag.3041
7. Biot, M. A. (1941). General Theory of Three-Dimensional Consolidation. *Journal of Applied Physics, 12*(2), 155–164. doi: 10.1063/1.1712886
8. Alejano, L. R., & Bobet, A. (2012). Drucker–Prager Criterion. *Rock Mechanics and Rock Engineering, 45*(6), 995–999. doi: 10.1007/s00603-012-0278-2
9. Tercaghi, K. (2008). *Theoretical Soil Mechanics*. New York: Wiley.
10. Yuzevych, V. M., Dzhala, R. M., & Koman, B. P. (2018). Analysis of Metal Corrosion under Conditions of Mechanical Impacts and Aggressive Environments. *Metallofizika i Noveishie Tekhnologii, 39*(12), 1655–1667. doi: 10.15407/mfint.39.12.1655
11. Yuzevych, L., Yankovska, L., Sopilnyk, L., Yuzevych, V., Skrynkovskyy, R., Koman, B., Yasinska-Damri, L., Heorhiadi, N., Dzhala, R., & Yasinskyi, M. (2019). Improvement of the toolset for diagnosing underground pipelines of oil and gas enterprises considering changes in internal working pressure. *Eastern-European Journal of Enterprise Technologies, 6*(5), 23–29. doi: 10.15587/1729-4061.2019.184247
12. Yuzevych, V., Pavlenchyk, N., Zaiats, O., Heorhiadi, N., & Lakiza, V. (2020). Qualimetric Analysis of Pipelines with Corrosion Surfaces in the Monitoring System of Oil and Gas Enterprises.

International Journal of Recent Technology and Engineering, 9(1), 1145–1150. doi: 10.35940/ijrte.a1341.059120

13. Lozovan, V., Skrynkovskyy, R., Yuzevych, V., Yasinskyi, M., & Pawlowski, G. (2019). Forming the toolset for development of a system to control quality of operation of underground pipelines by oil and gas enterprises with the use of neural networks. *Eastern-European Journal of Enterprise Technologies, 2*(5), 41–48. doi: 10.15587/1729-4061.2019.161484
14. Yuzevych, V., Skrynkovskyy, R., & Koman, B. (2018). Intelligent Analysis of Data Systems for Defects in Underground Gas Pipeline. *2018 IEEE Second International Conference on Data Stream Mining Processing*. doi: 10.1109/dsmp.2018.8478560
15. Yuzevych, L., Skrynkovskyy, R., & Koman, B. (2017). Development of Information Support of Quality Management of Underground Pipelines. *EUREKA: Physics and Engineering, 4*, 49–60. doi: 10.21303/2461-4262.2017.00392

Synthetic Modification of Sunflower Oil

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Abstract. This report is based on the synthesis of thermoset resins from sunflower oil. Sunflower oil with an iodine value of 120 g I / 100 g oil containing 30 % oleic acid and 59 % linoleic acid was epoxidized by reaction with a peroxy acid (formed in-situ by the reaction between hydrogen peroxide and formic acid). The ratio of ethylenic unsaturation to hydrogen peroxide to formic acid used was 1:1.5:0.5. The maximum conversion of iodine generated was 82.45 % for seven h of epoxidation at 65 °C, and the oxirane oxygen content at that same condition was 4.6 %. Thermoset resins synthesized from sunflower oil were further modified using acrylic acid. All the resins generated were characterized using FT-IR spectroscopy. The results showed that the generated resins could be used in composite production for automobile, construction, and furniture applications.

Keywords: sunflower oil; epoxidation; thermoset resins; acrylation; Oxirane Oxygen Content.

INTRODUCTION

Petrochemical-based polymers have been of great use due to their low cost, high mechanical performance, good heat sealability, and good barrier properties. One of the most important uses is in the composite making. Composite materials were made by embedding synthetic fibres such as carbon, aramid, glass, or natural fibres into a polymer matrix. However, the composite material produced from petrochemical-based polymers and earlier mentioned systematic fibres is not biodegradable. Also, these petrochemical-based polymers emit volatile organic compounds, negatively influencing human health and the environment [1]. Owing to the environmental problems generated by the disposal of conventional plastics and related polymers from petrochemicals, there has been intensified research into polymers originating from renewable resources [2].

Polymer matrix could be obtained from thermoplastic or thermoset polymers. Some examples of biobased thermoplastics may be polylactic acid or starch-based thermoplastics. Thermoset has the advantage of low viscosity, which makes fibre impregnation easy and room temperature processing by infusion techniques possible. The setback of the thermoset is that it cannot be remoulded after curing [3].

The most interesting raw material candidate for bio-based thermoset can be found amongst plant seed oils such as sunflower, castor, groundnut, soybean, cottonseed, linseed, or rapeseed. Plant oil is also known as a natural triglyceride. Triglycerides are esters of fatty acids and glycerol [4-5]. It needs to be functionalized to add cross-linkable sites to the fatty acids of the triglycerides or so that they can undergo further chemical reactions, so to say [6]. This chemical modification utilizes the unsaturated double bonds in the fatty acids part of the triglyceride. A good number of bio-based resins can be synthesized from plant oils. For example, epoxidized sunflower oil [7], acrylate epoxidized soybean oil (AESO), methacrylate soybean oil (MSO), and methacrylic anhy-

dride modified soybean oil (MMSO) [2]. Following composite application, these bio-based resins are then impregnated with natural fibres (referred to as reinforcement or fillers), such as flax, hemp, viscose, or lyocell fibres, to produce biodegradable composites. Scientists, researchers, and educational institutes are making great efforts [8].

The development of these bio-based resins has helped in the reduction of the use of fossil resources. They have been used in different applications, such as paints, inks, coatings, and plasticizers, and many technical products, such as housing (doors, composite decking, window frames, and hot tubs), aerospace (wings, tails, propellers, and fuselages), pipes and fittings, boat, storage tanks swimming pool panels and more popularly in the building of vehicle parts.

This is due to their biodegradability and inexpensive nature [1, 9]. This work discussed in detail the procedures and the outcome of the modification of sunflower oil. Using conventional plastics and related polymer materials derived from petrochemicals has posed more significant environmental concerns. There is a need for available alternatives from the bio-based origin; hence, this study.

Given the environmental issues associated with the disposal of conventional plastics and related polymers from petrochemicals, this project aims to develop novel thermosetting polymers derived from sunflower oil, which is of renewable origin. Therefore, the target is to create lighter weight, higher strength, and more eco-friendly materials and offset the reliance on petroleum-based materials in making thermoset resins. These resins may be used in composites which can be applied in the automotive industry to save energy (due to low weight), reduce carbon dioxide emission, and improve fuel efficiency. This study will cover the epoxidation and further modification of pure sunflower oil with acrylic acid.

MATERIALS AND METHOD

Materials. Pure sunflower oil was obtained from New Market (Aba, Abia State, Nigeria). Formic acid (85 %) was purchased from Linsko chemicals Lt. (Aba, Abia State, Nigeria); hydrogen peroxide (30 wt%) was also obtained from Linsko Chemicals Lt. (Aba, Abia State), although the first sample test was done with a little amount of H_2O_2 from Chemical Engineering Analysis Laboratory (MOUAU, Abia State, Nigeria). The chemicals mentioned above were used to epoxidize the oil. For further modification, acrylic acid (94%) was purchased from Linsko Chemicals Lt. hydroquinone (99%) was used as a cross-linking inhibitor and sodium carbonate, used for washing derived samples, was also purchased from Linsko chemicals Lt.

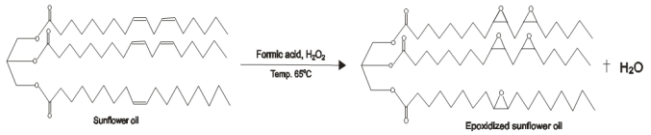
Resin Synthesis. Two different resins were synthesized from sunflower oil: Epoxidized Sunflower Oil resin (ESO) and Acrylated Epoxidized Sunflower Oil resin (AESO). The conventional method was used for the epoxidation of pure sunflower oil.

Experimental setup. Epoxidation reactions were carried out in a three-necked round-bottom flask (250 ml capacity) equipped with a magnetic heater/stirrer and placed in an oil bath, the temperature of which was controlled by the temperature regulator of the magnetic heater/stirrer to meet the desired temperature of the mixture inside the flask. The central neck of the flask was covered with a hollow cork through which a thermometer was introduced to record the temperature of the reaction mixture. In contrast, the remaining two necks were fitted with a reflux condenser and a reagent introduction tube; covered with a cork at the end (Figure 1).

Figure 1 – Experimental setup
(*also used for the acrylic modification process*)

Epoxidation procedure. The epoxidation method reported by [24] was used with slight variation in procedure, and this was repeated for all the experimental runs with the same concentration but different reaction times. A known

amount of sunflower oil (30 g) was placed in the flask, the calculated amount of formic acid was added to the flask after about five minutes, and the mixture was stirred continuously for 30 mins. Then 16.15 g of 30 wt% aqueous hydrogen peroxide was added dropwise to the reaction mixture, as an oxygen donor, at a rate such that the hydrogen peroxide addition was completed within half an hour, considering the completion of hydrogen peroxide addition as zero time. The mole ratio of the components used was 1:1.5:0.5, that is, ethylenic unsaturation: H_2O_2:HCOOH. After entirely adding hydrogen peroxide, the mixture was heated under reflux at the desired temperature (65 °C) and with rapid stirring. The rapid stirring was maintained throughout the experiment to achieve fine oil dispersion and avoid zones of high peroxide concentration that could lead to an explosive mixture. The reaction setup was repeated 5, 6, and 7 hours after the first 4-hour setup. The equation of reaction for the process is given below.



Scheme 1 – Synthesis of epoxidized sunflower oil

Washing of samples. The collected samples (ESO) were then immediately washed with sodium carbonate dissolved in distilled water to remove the free acids and other unreacted components. 10 g of Na_2CO_3 was first dissolved in 100 ml of distilled water. Then, another 100 ml of distilled water was further added to the mixture. The total mixture was added to the sample and separated by a funnel. Subsequent extraction was used to recover the remaining pieces after washing.

Determination of the Number of Chemicals Per Sample. Calculating the chemical required for the epoxidation reaction of the desired amount of oil, using formic acid as the oxygen carrier, is summarized below. Based on the literature, a typical fatty acid composition profile for sunflower oil is presented in Table 1.

Table 1 – Unsaturated fatty acid composition and molecular weight in sunflower seed oils

Fatty acids	Molecular formula	Composition (wt%)	Molecular weight (g/mol)
Oleic acid	$C_{18}H_{34}O_2$	59	282.47
Linoleic acid	$C_{18}H_{32}O_2$	59	280.45

The total mole of sunflower oil is expressed as the concentration of double bonds (DB) in the oil (a total of 89 %) → (n_t)

Mass of sunflower oil (chosen) = 30.0 g; Density of sunflower oil = 0.9188 g/ml; Volume of sunflower oil = 30.0/0.9188 = 32.65 ml.

$$n\ Oleic\ acid = \frac{0,3\times 30}{282.47} = 0.0319.$$

$$n\ Linoleic\ acid = \frac{0,59\times 30}{280.45} = 0.0631.$$

n_t = 0.0319 + 0.0631 = 0.095. A total mole of sunflower oil = 0.095 mol.

Formic acid. Mole ration of formic acid to DB = 0.5:1.

Formic acid (85 wt%), molecular weight = 46.03 g/mole, density = 1.22 g/ml. Mole of formic acid = 0.5, n_t = 0.5(0.095) = 0.0475 mol. Mass of formic acid = 0.0475(46.03) = 2.186 g.

$$Mass\ of\ formic\ acid\ solution = \frac{100\times 2.186}{85} = 2.57\ g$$

Volume of formic acid required per sample = 2.57/1.22 = 2.11 ml.

Hydrogen peroxide. Mole ration of hydrogen peroxide to DB = 1.5:1

Hydrogen peroxide (30 wt%), molecular weight = 34.01 g/mole, density = 1.10 g/ml; Mole of hydrogen peroxide = 1.5(0.095) = 0.1425 mole. Mass of hydrogen peroxide = 0.1425(34.01) = 4.85 g.

$$Mass\ of\ hydgen\ peroxide\ solution = \frac{100\times 4.85}{30} = 16.15\ g$$

Volume of hydrogen peroxide needed per sample = 16.15/1.10 = 14.68 ml.

Characterization of the epoxidized oil

Iodine Value and Oxirane Content analyses. These analyses were done on the epoxy resin to verify the degree of conversion of the pure oil to an epoxide.

FT-IR analysis. The first FT-IR Spectroscopy (Fourier transform infrared spectroscopy) analysis was done to verify the functionalization of the resin with the peroxyl acid (that is, hydrogen peroxide reacted with formic acid) in comparison with the known properties of the pure sunflower oil as obtained from the literature.

Synthesis of acrylate-modified sunflower oil. This is due to further modification of the epoxy resin with acrylic acid. The epoxidized sunflower oil (14.09 g) was heated at room temperature, while acrylic acid (4.6 g) containing hydroquinone (0.011 g; 0.25 wt% acrylic acid) was added for 30 minutes. The reaction mixture was heated under reflux for 6 hours at 120 °C with constant stirring. Excess acrylic acid (1.8 g) containing hydroquinone (0.0042 g) was added for 5 mins, and the reaction proceeded for another 2 hours at the same temperature. The mixture was cooled to room temperature, and the obtained product acylated epoxidized sunflower oil (AESO), was isolated. The synthesis was repeated for the remaining epoxidized samples.

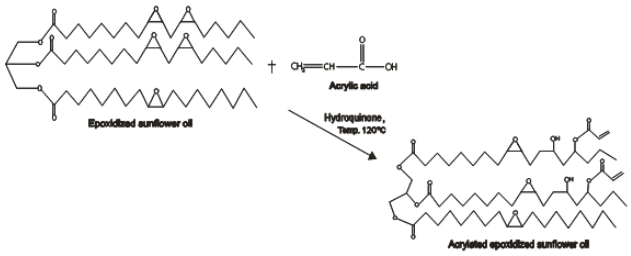


Figure 2 – Synthesis of acylated epoxidized sunflower oil

Characterization of acylated sunflower oil

FT-IR spectroscopy analysis was also employed to identify the fictionalization of the structure of the modified resin, and the comparison was made for the pure and epoxidized oil.

RESULTS AND DISCUSSION

Determination of Iodine Value and Conversion

The iodine value of sunflower oil was calculated using the equation below:

$$Iodine\ value = \frac{(B-S)\times M\times 12.69}{W}, \quad (1)$$

where S – volume of $Na_2S_2O_3$ solution required for titration of the sample (ml); B – volume of $Na_2S_2O_3$ solution required for titration of the blank (ml), W = weight of sample used (g); M – Molarity of the $Na_2S_2O_3$ (0.1 M).

The initial value of sunflower oil (IV_o) is expressed as iodine value at t = 0 (h), M = 0.10 M, W = 0.20 g, B_1= 23.75 ml, B_2= 23.76 ml, B_3= 23.74 ml, B_{AV} = 23.75 ml, S_1= 4.81 ml, S_2= 4.84 ml, S_3= 4.84 ml, S_{AV} = 4.83 ml.

$$IV_o = \frac{(23.75-4.83)\times 0.1\times 12.69}{0.20} = 120.05\ g\ I/100\ g\ oil$$

$$X_{\%} = \frac{IV_o - IV}{IV_o}\times 100, \quad (2)$$

where IV_o – Initial iodine value; IV – Iodine value at certain conditions; Reaction temperature = 65 °C (constant); Stirring speed = 750 rpm (constant).

a) Reaction time = 4 h, W = 0.20 g, S_1= 14.83 ml, S_3= 14.83 ml, S_3= 14.86 ml, S_{AV} = 14.84 ml.

$$IV = \frac{(23.75-14.84)\times 0.1\times 12.69}{0.20} = 56.53\ g\ I_2/100\ g\ oil$$

$$X_{\%} = \frac{120.05-56.53}{120.05}\times 100 = 52.91\%.$$

b) Reaction time = 5 h, W = 0.20 g, S_1= 16.39 ml, S_3= 16.42 ml, S_3= 16.39 ml, S_{AV} = 16.40 ml.

$$IV = \frac{(23.75-16.40)\times 0.1\times 12.69}{0.20} = 46.64\ g\ I_2/100\ g\ oil$$

$$X_{\%} = \frac{120.05-46.64}{120.05}\times 100 = 61.15\%.$$

c) Reaction time = 6 h, W = 0.20 g, S_1= 19.36 ml, S_3= 19.37 ml, S_3= 19.33 ml, S_{AV} = 19.35 ml.

$$IV = \frac{(23.75-19.35)\times 0.1\times 12.69}{0.20} = 27.92\ g\ I_2\ /100\ g\ oil$$

$$X_{\%} = \frac{120.05-27.92}{120.05}\times 100 = 76.74\ \%.$$

d) Reaction time = 7 h, W = 0.20 g, S_1= 20.42 ml, S_3= 20.45 ml, S_3= 20.42 ml, S_{AV} = 20.43 ml.

$$IV = \frac{(23.75-20.43)\times 0.1\times 12.69}{0.20} = 21.07\ g\ I_2\ /100\ g\ oil$$

$$X_{\%} = \frac{120.05-21.07}{120.05}\times 100 = 82.45\ \%.$$

The reaction conversions for 4–7 h are summarized in Figure 3 below.

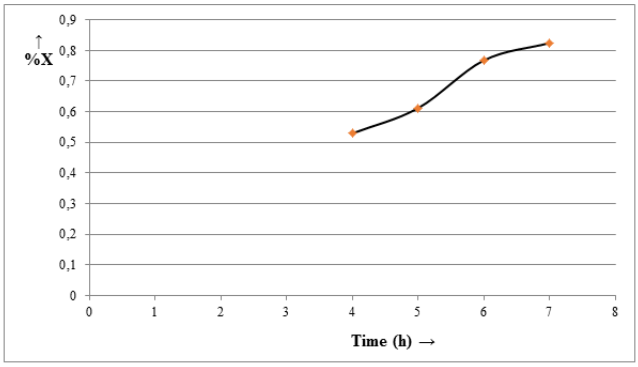


Figure 3 – Effect of time on Conversion to iodine value

Determination of oxirane oxygen content

The number of oxirane groups indicated by the percentage of oxirane was calculated using the equation below.

$$Oxygen\ content = \frac{(B-S)\times M\times 16\times 100}{W\times 1000}$$

where S – volume of NaOH used for sample (ml); B = volume of NaOH used for blank (ml); M – Molarity of the NaOH – 0.1 M; W – weight of sample used (g).

The volume of NaOH used for blank (ml)

B_1 = 22.89 ml, B_2 = 22.89 ml, B_3 = 22.92 ml, B_{AV} = 22.90 ml, Reaction temperature = 65 ˚C (constant), Stirring speed = 750 rpm (constant).

a) Reaction time = 4 h, W = 0.20 g, S_1= 19.31 ml, S_2= 19.36 ml, S_3= 19.32 ml, S_{AV} = 19.33 ml.

$$Oxygen\ content = \frac{(22.90-19.33)\times 0.1\times 16\times 100}{0.2\times 1000} = 2.86\ \%$$

b) Reaction time = 5 h, W = 0.20 g, S_1= 19.00 ml, S_2= 19.02 ml, S_3= 19.01 ml, S_{AV} = 19.01 ml.

$$Oxygen\ content = \frac{(22.90-19.01)\times 0.1\times 16\times 100}{0.2\times 1000} = 3.11\ \%$$

c) Reaction time = 6 h, W = 0.20 g, S_1= 18.96 ml, S_2= 18.89 ml, S_3= 18.96 ml, S_{AV} = 18.97 ml.

$$Oxygen\ content = \frac{(22.90-18.97)\times 0.1\times 16\times 100}{0.2\times 1000} = 3.14\ \%$$

d) Reaction time = 7 h, W = 0.20 g, S_1= 17.25 ml, S_2= 17.10 ml, S_3= 17.10 ml, S_{AV} = 17.15 ml.

$$Oxygen\ content = \frac{(22.90-17.15)\times 0.1\times 16\times 100}{0.2\times 1000} = 4.60\ \%$$

The oxirane conversion for 4–7 h are summarized in Figure 4.

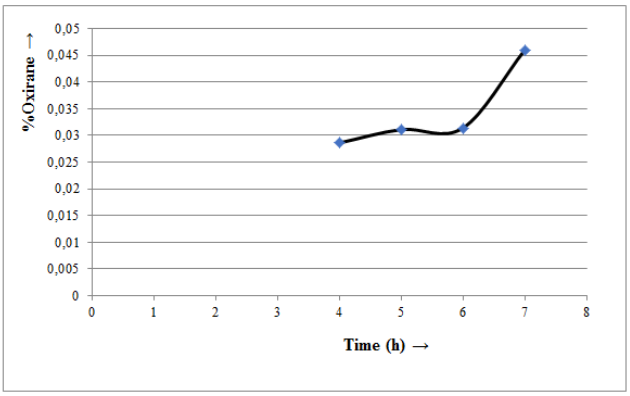


Figure 4 – Effect of time on conversion to oxirane content

Resins from Epoxidation and Acrylation Reactions. Four epoxy resins were synthesized from pure oil. Further modification of the epoxidized oils with acrylic acid yielded four acrylates epoxidized resins. Figure 5 shows examples of one out of the polishes from the epoxidation and further improvement (with acrylic acid) of pure sunflower oil.

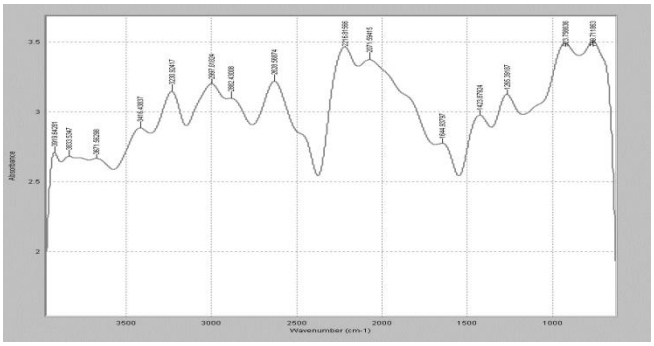
a) A sample of ESO b) A sample of AESO

Figure 5 – Examples of generated epoxy and acrylate-modified resins

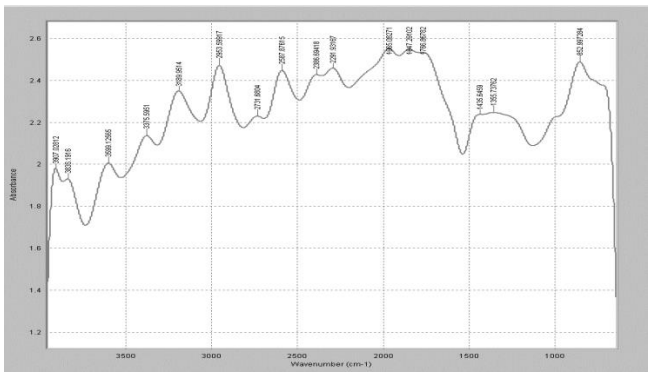
FT-IR spectroscopy analysis. The FT-IR spectroscopy of the untreated oil and the epoxy and further modified resins of sample 3 are shown in Figure 6. This sample was chosen because it showed the highest response. The FT-IR spectra were used to verify the ESO functionalization with acrylic acid and to compare the ESO and the acrylate resin with the untreated oil.

The iodine value and oxirane oxygen content are important properties in the characterization of epoxidized vegetable oils. While the Iodine value indicates the remaining unsaturation after the epoxidation reaction, the oxirane oxygen content indicates the epoxy groups present in the products. In the preparation of polymer, epoxy resins with lower iodine values and higher oxirane oxygen content are desired. The reduction in iodine values indicates the consumption of the unsaturation during epoxidation. But there did not represent conversion solely to epoxy groups because epoxy ring degradation generates side reactions.

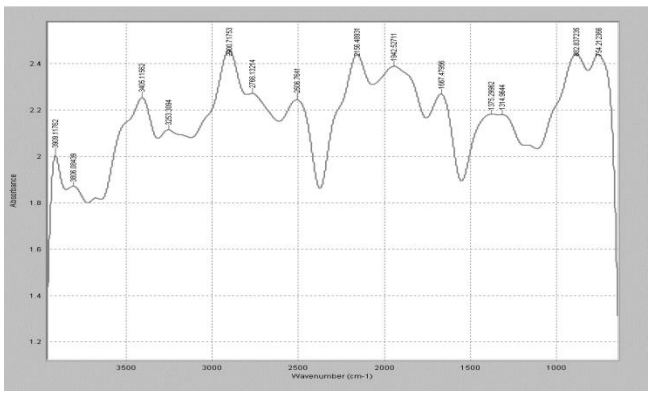
The effect of time on iodine value and reaction conversation is shown in Figure 3. The result indicated that the conversion of iodine value in the sunflower oil increases linearly with an increase in reaction time. Also, the effect of reaction time on oxirane content is shown in Figure 4. The result indicates that oxirane content increases with time. Unsaturated double bonds in the oil were converted to an oxirane ring through an epoxidation reaction, as indicated by the decrease in iodine value. Maximum conversion of 82.45% (with iodine value of 21.07 g I2 / 100 g oil) was achieved at seven h reaction time and 65 ˚C. The corresponding oxirane content was gotten to be 4.60 % at the same conditions. Hence the optimum operating condition for the epoxidation reaction was achieved at a reaction time of 7 h.



a) Untreated Oil



b) ESO



c) AESO

Figure 6 – FT-IR spectra of untreated, epoxidized, and acrylic-modified sunflower oil

For modification with acrylic acid, the esterification reaction took place between the epoxidized sunflower oil and acrylic in the presence of hydroquinone (as a cross-linking inhibitor). The epoxy group reacted with the carboxylic acid to form esters. The reaction occurred between the acid's carboxyl group and the epoxy and hydroxyl group of the epoxides. This resulted in the formation of acrylate epoxidized sunflower oil.

In the FT-IR spectra, it can be seen that the presence of carbon-carbon double bonds (C=C) in the untreated sunflower oil was indicated by the appearance of a peak at 1520 cm^{-1}. The single rise marked the absorption band for the epoxy group in ESO at 842 cm^{-1}, achieved after seven h reaction time and 65 °C temperature. This peak was missing in the untreated oil. The hydroxyl absorption is shown by the slope, down from 3900 cm^{-1}. The peak indicates the IR spectra for the acrylic group at 1690 cm^{-1}. This peak is absent in both the epoxy resin and the untreated sunflower oil, which shows that the acrylate resin was formed.

CONCLUSIONS

The environmental issues associated with petrochemical polymer materials brought about the need for using materials from renewable sources. Renewable raw materials are environmentally friendly, biodegradable, low-cost, and readily available. The most interesting raw materials candidate for bio-based thermosets can be found among plant seed oils, also known as triglycerides. Sunflower oil is an excellent example of plant seed oil. An effort is being made to produce 100% bio-based thermosetting materials. This report is based on the synthesis of thermoset resin from sunflower oil. From the results, it could be seen that biobased material could serve as a possible replacement showing that the generated composite could be used in automobile, construction, and furniture applications.

We are recommend further studies to be carried out, first by the use of other methods of vegetable oil modification apart from epoxidation and acrylation. Secondly by the extension of the reaction time to 10 hours and above (also beginning from zero hours), to determine the response at a higher number of hours. We also recommend using computer software such as design expert to model the process.

REFERENCES

1. Bakare, F. O. (2015). *Development of biocomposites from lactic acid thermoset resin and cellulose fibre reinforcements*. Retrieved from http://hb.diva-portal.org/smash/get/diva2:793106/FULLTEXT01.pdf
2. Adekunle, K., Ãkesson, D., & Skrifvars, M. (2010). Synthesis of reactive soybean oils for use as a biobased thermoset resins in structural natural fiber composites. *Journal of Applied Polymer Science, 115*(6), 3137–3145. doi: 10.1002/app.31411
3. Adekunle, K. F. (2011). *Bio-based Composites from Soybean Oil Thermosets and Natural Fibers*. Retrieved from https://www.hb.se/globalassets/pagefiles/33483/abstract_kfa.pdf
4. Khot, S. N., Lascala, J. J., Can, E., Morye, S. S., Williams, G. I., Palmese, G. R., Kusefoglu, S. H., & Wool, R. P. (2001). Development and application of triglyceride-based polymers and composites. *Journal of Applied Polymer Science, 82*(3), 703–723. doi: 10.1002/app.1897
5. O'Donnell, A., Dweib, M. A., & Wool, R. P. (2004). Natural fiber composites with plant oil-based resin. *Composites Science and Technology, 64*(9), 1135–1145. doi: 10.1016/j.compscitech.2003.09.024
6. Helminen, A. O., Korhonen, H., & Seppälä, J. V. (2002). Structure modification and crosslinking of methacrylated polylactide oligomers. *Journal of Applied Polymer Science, 86*(14), 3616–3624. doi: 10.1002/app.11193
7. Cai, C., Dai, H., Chen, R., Su, C., Xu, X., Zhang, S., & Yang, L. (2008). Studies on the kinetics of in situ epoxidation of vegetable oils. *European Journal of Lipid Science and Technology, 110*(4), 341–346. doi: 10.1002/ejlt.200700104
8. Adekunle, K., Ãkesson, D., & Skrifvars, M. (2010). Biobased composites prepared by compression molding with a novel thermoset resin from soybean oil and a natural-fiber reinforcement. *Journal of Applied Polymer Science, 116*(3). doi: 10.1002/app.31634

9. Koronis, G., Silva, A., & Fontul, M. (2013). Green composites: A review of adequate materials for automotive applications. *Composites Part B: Engineering, 44*(1), 120–127. doi: 10.1016/j.compositesb.2012.07.004

10. Goud, V. V., Patwardhan, A. V., & Pradhan, N. C. (2006). Studies on the epoxidation of mahua oil (Madhumica indica) by hydrogen peroxide. *Bioresource Technology, 97*(12), 1365–1371. doi: 10.1016/j.biortech.2005.07.004

Biosorption of Chromium (II) Ion from Textile Effluent Using Watermelon Shell-Activated Carbon

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Abstract. Watermelon Shell, an agricultural waste, was employed for the adsorptive removal of chromium (II) ion Cr^{2+} from textile effluent. This study analysed the adsorbent's active sites and morphological structures using FT-IR, SEM, XRD, and XRF. The independent variables' effect, contact time, adsorbent dosage, and pH were predicted using Response Surface Methodology (RSM) for chromium adsorption onto Watermelon Shell Activated Carbon (WSAC). The experimental results indicated that NaOH activation effectively improved WSAC's adsorption capacity. The maximum adsorption capacity was 54.53 %, with an adsorbent dosage of 0.6 g/l, pH of 6.0, and agitation time of 40 min. The high correlation coefficient (R^2=0.978) between the model and the experimental data showed that the model predicted the removal of Cr^{2+} from textile effluent using Watermelon Shell Activated Carbon efficiently.

Keywords: Activated Carbon; Chromium Adsorption; Heavy Metals; Adsorption; Watermelon Shell; Textile Effluent; Carbonisation.

INTRODUCTION

Wastewater is any water whose quality has been negatively impacted by human activity. Wastewater can originate from domestic, industrial, commercial, or agricultural activities, surface runoff or stormwater, and sewer inflow or infiltration [1]. Significant health hazards are related to using untreated wastewater for domestic purposes, agriculture, etc. The presence of heavy metals in wastewater is one of the most challenging environmental problems due to their toxicity, persistence, and bioaccumulation tendencies [2]. Many industries produce and discharge metal-containing wastes mostly into water bodies. This affects the water's aesthetic quality and increases the concentrations of metals present [3]. These heavy metals commonly include; Cd, Pb, Cu, Fe, Ni, Mn, and Cr. Heavy metal contamination is not a recent problem, but its management and prevention are still of global concern [4]. Textile industries contribute immensely to surface water deterioration and are categorised among the most polluting in all industrial sectors [5]. The dyeing and printing of textiles have a significant environmental impact since they use a lot of water and generate a lot of highly contaminated wastewater.

The pollutants created by the textile dyeing and printing industries are influenced by the chemicals used in the various dyeing and printing processes. The receiving water thus becomes brackish. Textile dyes are toxic, highly stable and do not degrade quickly, and are not removed by conventional wastewater treatment methods. Due to the environment's non-degradable nature and long-time persistence, the toxic waste often accumulates at a low level, causing a harmful biological effect [6].

In addition, effluent or wastewater from textile production discharged into the water body without proper treatment also seeps through the aquifer and pollutes the underground water in many ways. Besides colour visibility which brings displeasing aesthetics, heavy metal constituents in the effluent also result in adverse environmental impacts on the water body and environment as well as deterioration of human health [7].

During operations, they also produce heat from effluents released, increased pH, and water saturation with dyes, defoamers, bleaches, detergents, optical brighteners, and equalisers. Due to these, pollutants from the textile production sector are being released into the environment at various stages of operation. Heavy metals, notably lead (Pb), Chromium (Cr), cadmium (Cd), and copper (Cu), are used widely for the colour pigment production of textile dyes. Such heavy metals can exist naturally in the structures of textiles or penetrate textile fibres during the show, the dyeing process, or through protective agents used during storage. These heavy metals, which have been transferred to the environment, are highly toxic and can bioaccumulate in the human body, aquatic life, and natural water bodies and possibly be trapped in the soil [8].

Lead (II) ion has been reported to be responsible for intellectual disabilities in children and causes about 143,000 deaths annually in developing countries [9]. Young children are vulnerable to lead exposure because it affects the development of the brain and nervous system [10]. It can also result in miscarriage, low birth weight, stillbirth, premature birth in pregnant women, kidney damage, and high blood pressure in adults [11]. Ingestion of lead-contaminated water has been implicated as a significant route of lead toxicity.

Several techniques have been designed for heavy metals removal from aqueous solutions, including ion exchange, chemical precipitation/co-precipitation, filtration, coagulation, membrane technologies, and commercial activated carbon [12]. The significant drawbacks to these methods lie in the cost involved, the efficiency of the processes, and the disposal of wastes generated [13]. These disadvantages have made researchers seek alternative techniques for heavy metal remediation.

Hazardous metals can reportedly be removed from industrial effluents by adsorbing using naturally occurring elements. This method uses dead waste biomass, microorganisms, and other naturally plentiful plant components as raw materials [14]. The sorption capacity of some bio sorbents is high due to the presence of adequate functional groups that sequester metals from aqueous solutions [13]. This method's application is affordable, sustainable, and readily available. These bio-based materials have demonstrated a propensity to eliminate metals at trace levels, thereby addressing some of the major drawbacks of conventional techniques [15]. Several adsorbents from plant origin have been used and modified for heavy metal removal from wastewater and aqueous solution, which include: maise tassels, coffee beans, coconut shells, peanut shells, Annona squamosal shells, rice husks, rice bran, orange peels, sunflower stem, groundnut shells and avocado seed [16, 17]. This study presents Watermelon Shell Activated Carbon as a potential, environmentally friendly, and low-cost adsorbent for the adsorption of metals from textile wastewater samples. In Watermelon, the red flesh inside is sweet, edible, and used for juices and salads, but the outer shell is considered waste and has no commercial value [18].

The watermelon shell consists of pectin, citrulline, cellulose, proteins, and carotenoids [19]. The polymers are rich in functional groups like hydroxyl (cellulose) and carboxylic (pectin). They can easily bind metal ions by changing their hydrogen ions for metal ions or giving an electron pair to form complexes with the metal ions [20]. The idea behind the adsorption of heavy metals using watermelon shells is to treat waste with waste and become even more effective because these agricultural by-products are easily accessible and frequently cause issues with garbage disposal.

Because they are waste items, they can be found for little to no money. Also, this makes treating wastewater with agricultural by-product adsorbents more economical than using conventional adsorbents like activated carbon. This research conducted characterisation and optimisation studies for textile effluent and watermelon shells.

MATERIALS AND METHODS

Effluent Collection. The raw effluent was collected from Rosie's textile Company in Aba, Abia state, in a sterile 20 litres gallon from its point of discharge to the environment. It was stored at room temperature without further purification [21].

Collection of Adsorbent. Watermelon shells (WS) were obtained from different fruit-selling sources in Umuahia, Abia state, and washed with clean water. The watermelon shells were cut into small pieces and dried in sunlight for 14 days to remove all moisture content present. The dried watermelon shells were stored in an air-tight container.

Carbonisation. Carbonisation (1500 grams of washed, cut, and dried watermelon shells) was carried out in a muffle furnace (KGYV BUDAPEST KCC086/50-120.3 phases) at about 500-700 °C for two hours and was held at this temperature for 60 min, after which the charred products were allowed to cool to room temperature.

Preparation of 60% Alkaline (NaOH) Used for Activation. 40 g of NaOH pellet was carefully weighed using an electronic balance (YP502N) and dissolved in 1000 ml of distilled water using a measuring cylinder. 400 ml of the dissolved NaOH was removed and stored in an air-tight container. The remaining 600 ml of the dissolved NaOH was diluted up to 1000 ml of NaOH solution with distilled water. This gave the required 60% solution of NaOH.

Preparation of Activated Carbon. The charred material obtained from watermelon shell carbonisation was crushed into smaller sizes to pass through a 3 mm sieve and retained in a 1.5 mm sieve. 302 g of the sample was weighed using an electronic balance (YP502N) and impregnated in the alkaline solution (60 % NaOH) in a beaker. The mixture was stirred with a glass rod to mix well and left for 24 hours for proper impregnation. At the end of the 24 hours, the mixture was washed with distilled water until the tested pH of the water washed out became near neutral [22]. The sample was dried in an oven for 1 hour at 105 °C and stored in an air-tight container.

Textile Effluent Characterization. The effluent was analysed for the presence of heavy metals (nickel, vanadium, zinc, lead, calcium, manganese, chromium, sodium, iron, and copper) by digesting 100 ml of the effluent using a 10 ml triple acid mixture (5:1:1 - HNO_3:$HClO_4$:H_2SO_4) in a 250 ml conical flask. The sample was properly covered with aluminium foil to avoid spillage and heated on a hot plate until the solution was reduced to 10 ml. After that, it was allowed to cool and make up to a mark by topping with distilled water before it was filtered into a 50 ml standard flask ready for further analysis. The concentrations of the heavy metals in the wastewater were determined using Atomic Absorption Spectrometer (AA-7000). The result is given in Table 1.

Batch Adsorption. 100 ml of the textile effluent was transferred to 250 cm^3 Erlenmeyer flasks after the initial pH of the sample's effluent had been determined. 0.2 g of Watermelon Shell Activated Carbon (WSAC) was weighed and added to the effluent. The solution was agitated for 10 min using a speed-adjusting multipurpose vibrator (HY-2) at 100 rpm. Adsorbent dose, contact time, pH, and beginning concentration were among the adsorption parameters whose effects were investigated. Using 0.1 M HCl and 0.1 M NaOH as adjustments, the impact of pH on adsorption was assessed by altering the pH from 2–10. The contact period was changed from 10 to 70 min, and the adsorbent dosage was changed from 0.2 to 1 gram per litre to determine its impact. The solid phase was separated for each parameter study using filter paper, and the remaining metal concentration in the supernatant was assessed using an atomic absorption spectrophotometer (MODEL: AA-700).

Adsorbent Characterization

Proximate Analysis. Proximate analysis was carried out on the WSAC to determine the moisture content, ash content, fat content, crude protein, crude fibre, and carbohydrate using AOAC 2005 method. The result is presented in Figure 5.

FTIR Analysis. The sample was analysed using FTIR technology of the mark SPECTRUM ONE FTIR combined with software (Perkin Elmer Instruments version 3.02.01) to study the spectra. 0.5 g of activated carbon was added to the spectrophotometer for sample analysis. For sample analysis, 0.5 g of activated carbon was introduced into the spectrophotometer for analysis. The wave number varied between 4000 and 350 cm^{-1}.

X-ray Fluorescence (XRF) Analysis. This was performed to know the chemical compositions of the minerals in the adsorbent. X-ray fluorescence analysis of the adsorbent was done using model PW 2400/0.

X-ray diffraction (XRD) Analysis. X-ray (XRD-6000 SHIMADZU Japan) was used to scan the activated carbon used in this work. This was done at 2θ value between 100 and 800 at a scan rate of 2 degrees per minute.

Scanning Electron Microscope Analysis. A scanning electron microscope (SEM) was used to determine the morphological structure of the activated carbon before and after adsorption.

Adsorption Kinetics and Isotherms

Kinetics of Adsorption. The kinetics of adsorption was examined by examining the adsorptive uptake of heavy metals from wastewater at various time intervals. The pseudo-first-order and pseudo-second-order model equations were used to simulate the rate at which heavy metals bind to the created activated carbon.

The linearity of each model was plotted. As a result, in this work, the model parameters were calculated utilising the data produced by the experiments performed and considering the linearised forms of the pseudo-first-order and pseudo-second-order reaction models, respectively.

$$log(q_e - q_t) = log(q_e) - \frac{k_1}{2.303}t \quad (1)$$

$$\left(\frac{t}{q_t}\right) = \frac{1}{k_2 q_e^2} + \frac{1}{q_e}(t) \quad (2)$$

Adsorption Isotherm. With the aid of the data generated from the adsorption studies of this work, the parameters contained in the Langmuir adsorption isotherm were estimated.

$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \quad (3)$$

The linearisation of equation (3) leads to the following form:

$$\frac{1}{q_e} = \frac{1}{q_m k_L C_e} + \frac{1}{q_m} \quad (4)$$

Experimental Design. The design and analysis of variables were evaluated using Design-Expert V6.0.8. Response surface methodology (RSM) is a statistical method that uses quantitative data from appropriate experiments to determine regression model equations and operating conditions. A standard RSM design called Box-Behnken Design (BBD) was applied in this work to study the variables for removing chromium from an aqueous solution using a batch process. BBD was used as an experimental design model for three variables (adsorbent dosage, pH of resolution, and agitation time), each with three levels (the minimum, medium and maximum). Seventeen experiments [22] are needed to conduct and determine ten coefficients of the second-order polynomial equation [23]. In the experimental design model, adsorbent dosage (0.2-1.0 g/l), pH (2-10), and agitation time (10-70 min) were taken as input variables. The percentage removal of chromium was taken as the response of the system. Three factors were studied, and their low and high levels are given in Table 1.

Table 1 – Coded and actual values of variables of the experimental design

Factor		Coded levels of variables		
		-1	0	1
Adsorbent dosage	A	0.2	0.6	1.0
pH	B	2	6	10
Agitation time	C	10	40	70

RESULTS AND DISCUSSION

Textile effluent and proximate analysis. The result of the characterisation of the textile effluent before adsorption (Table 2), conducted using an Atomic Absorption Spectrometer (AA-7000), indicated the presence of heavy metals.

Table 2 – Characterisation of textile effluent before adsorption

Metals	Concentration
Calcium, ppm	3.3333
Chromium, ppm	1.3333
COD	170.4
Sulphate	18.24
Manganese, ppm	0.0324
Sodium, ppm	1.4883
Vanadium, ppm	2.0000
Zinc, ppm	0.0693
Nickel, ppm	0.2051
TOC	8.78
Ph	6.41
BOD, m/l	51.2
Chloride	252.76
Nitrate	16.08
Phosphate	1.5
TDS	758.87

After the proximate composition characterisation of the activated carbon (Table 3), the result stated fixed carbon content of 80.37% at a 25.7% yield.

Table 3 – Proximate composition analysis results of WSAC

Parameter	Result
Moisture content (%)	24.50
Ash (%)	17.50
Volatile matter (%)	14. 25
Surface area (m^2/g)	847.43
Fixed carbon (%)	80.37
Bulk density (gcm^2)	0.4
Iodine number	724.64
Yield (%)	25.7

FTIR Analysis. The FT-IR spectra of unloaded WSAC (Fig. 1a) indicated a band at 3395.79 cm^{-1} due to the O–H stretching of water. The band observed at 2935.76 cm^{-1} corresponded to methylene asymmetric, H–H stretching. The band at 1592.29 cm^{-1} indicated the presence of pyridine, C=N stretching, while the band at 1402.3 cm^{-1} was ascribed to azo compound, N=N stretching. Finally, the band at 1084.03 cm^{-1} was found to be due to aliphatic C–N stretching, while the band at 683.79 cm^{-1} was due to P=S stretching. After the adsorption of the metal ions present in the effluent by the activated carbon, the FT-IR spectra (Figure 1b) showed shifts in some of the bands and new bands. For instance, the bands at 406.03, 683.79, 1084.03, 1403, 1592.29, 2935.76, and, 3395.79 cm^{-1} were shifted to 408.92, 786.02, 1099.46, 1399.4, 1599.04, 2934.79 and 3400.62 cm^{-1}, respectively. The shifts in the bands confirmed the participation of the functional groups in the adsorption of the metal ions of the effluent onto the developed activated watermelon shell carbon.

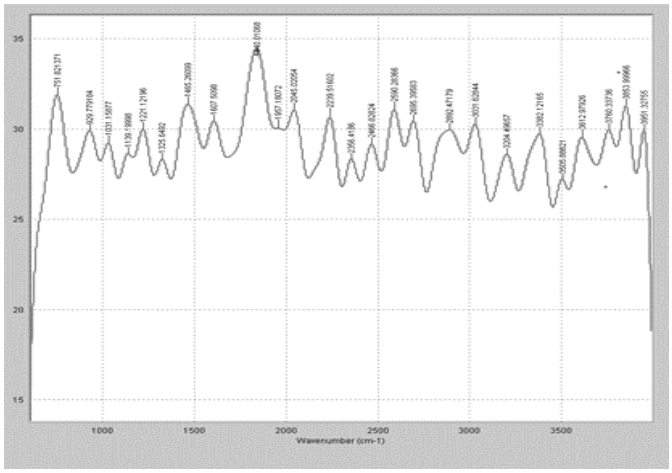


Figure 1a – FT-IR spectrum for WSAC before adsorption

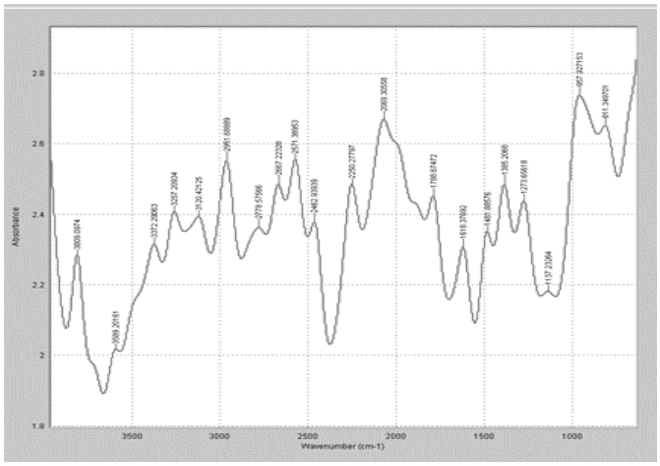


Figure 1b – FT-IR spectrum for WSAC after adsorption

XRF Analysis. From the result of the XRF before and after the biosorption (Table 4), the concentration of silica oxide (SiO_2) was 83.70%, the highest among the chemical composition. It shows that the loading of Cr was 24.40% after biosorption.

Table 4 – XRF chemical analysis of the WSAC samples

Formula	Concentration before adsorption (%)	Concentration after adsorption (%)
CO_2	0.10	0.1
SiO_2	83.70	1.18
SO_3	8.32	0.93
CaO	2.18	0.15
Al_2O_3	1.61	0.26
Fe_2O_3	1.00	1.34
P_2O_5	0.99	0.003
K_2O	0.87	0.20
Cl	0.82	0.11
MoO_3	0.30	0.05
Cr	ND	24.40

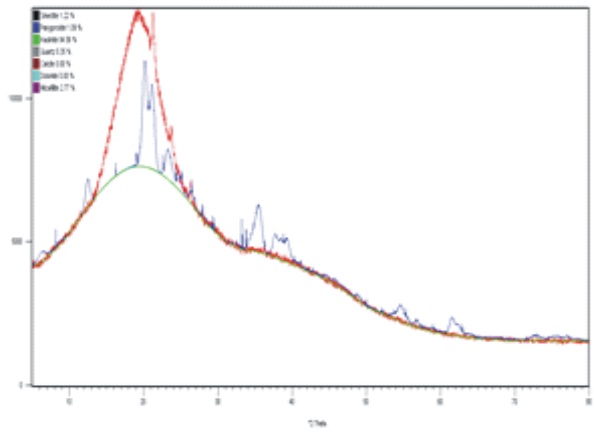
X-ray diffraction analysis (XRD). The WSAC has an utterly amorphous structure which is expected for organic materials. Sharp peaks are absent, revealing a predominantly amorphous structure, an advantageous property of a well-defined porous adsorbent [24]. The X-ray diffraction pattern of the samples in Figure 2 shows the presence of mica/illites, kaolinite, and quartz.

The reflection associated with mica/illites is characterised by reflection located at 2θ=17° and 25° and kaolinite at 2θ=20° and 21° for WSAC before adsorption. For WSAC after adsorption, mica/illites were located at 15°, 18°, and 24°, and kaolinite at 20° and 22°.

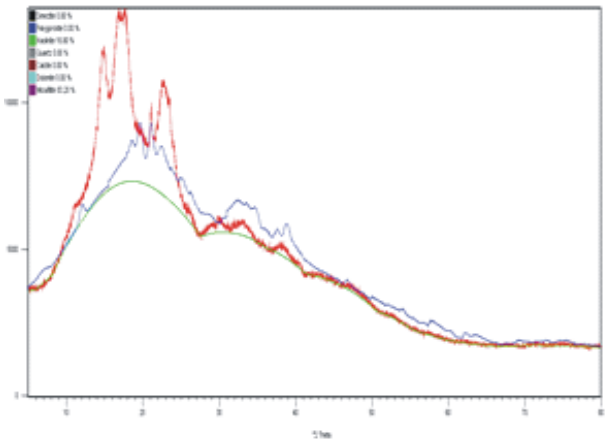
Table 5 – X-ray diffraction results for the adsorbent

Phase	Before	After
Smectite	0.15	0.00
Palygorskite	0.00	0.82
Kaolinite	0.00	2.87
Quartz	16.90	15.74
Calcite	0.85	0.61
Dolomite	0.57	2.37
Mica/illite	81.54	77.59

Other reflections are attributed to the activated carbon, like smectite, palygorskite, calcite, and dolomite. Other researchers also reported this outcome [27].



a)



b)

Figure 2 – X-ray diffraction pattern of WSAC before (a) and after (b) adsorption

Morphology and Textural Examination of the Adsorbent. From the SEM results (Figure 3a), the watermelon shell gave a porous surface texture, enabling metal ions' adsorption onto the surface. Besides, it also shows that the surface morphology of the watermelon shell consisted of two kinds of colour tones: lighter and darker [26].

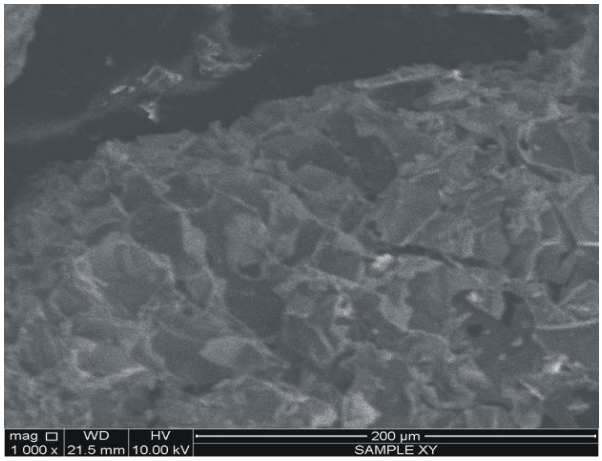


Figure 3a – SEM image of WSAC before adsorption 1000 magnification

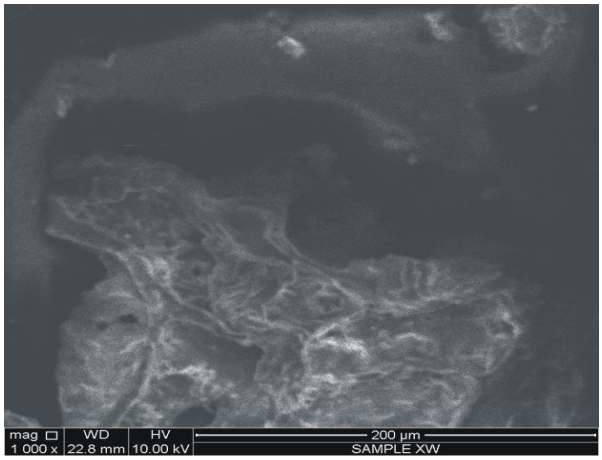


Figure 3b – SEM image of WSAC after adsorption at 1000 magnification

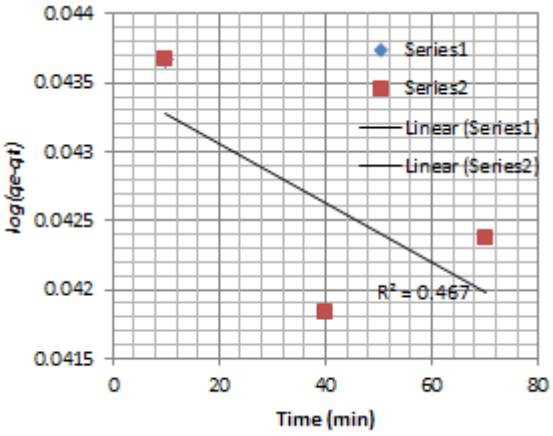
The lighter shades represented the inorganic component, while the darker shades were organic components. From the spectrum of the watermelon shell (Figure 3a), Si was observed. After the biosorption of Cr using a watermelon shell, the morphology underwent a physical change. Lump-like deposits or shiny particles were formed (Figure 3b).

Adsorption Kinetics. The pseudo-first-order and pseudo-second-order model equations were fitted to model the kinetics of heavy metal adsorption onto the produced activated carbon. When plotted, the linearity of each model was used to determine how suitable each model was for the adsorption. As a result, the model parameters were calculated in this study utilising the data produced by the experiments conducted and taking into account the linearised versions of the pseudo-first-order and pseudo-second-order reaction models provided in Equations (5) and (6), respectively.

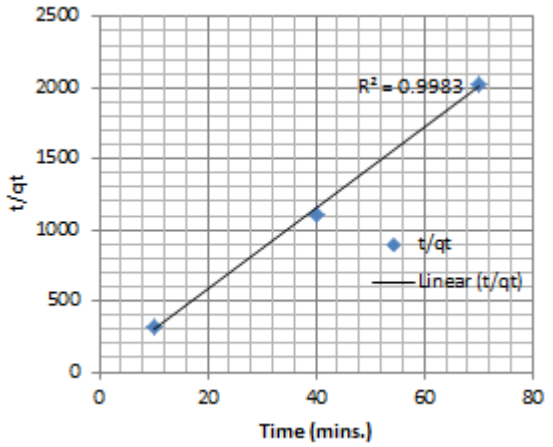
$$log(q_e - q_t) = log(q_e) - \frac{k_1}{2.303}t \quad (5)$$

$$\left(\frac{t}{q_t}\right) = \frac{1}{k_2 q_e^2} + \frac{1}{q_e}(t) \quad (6)$$

It was found that the pseudo-second-order model fitted better than the pseudo-first-order model for the removal of Cr^{2+} by Watermelon with R^2=0.9983 (Figure 4).



Pseudo-first-order kinetic



Pseudo-second-order kinetic

Figure 4 –Pseudo first and Second-Order plot for Cr^{2+} Removal by WSAC

Adsorption isotherm. The results obtained from chromium adsorption using 100 ml textile wastewater and 0.6 g WSAC at 40 min agitation time and pH of 6 (Figure 5) gave an R^2 value of 0.9993.

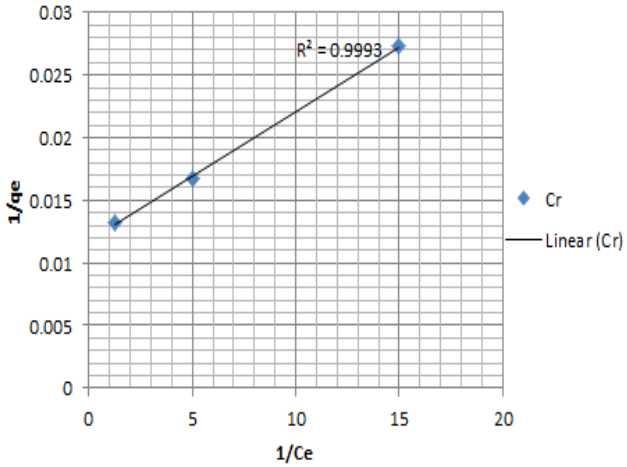


Figure 5 – Langmuir adsorption isotherm for adsorption of Cr2+ on WSAC

Statistical Optimization of Removal of Chromium Using WSAC. A BBD with a total of 17 experiments was employed for RSM. Table 6 reports the experimental and predicted values of the adsorption capacity of WSAC.

Table 6 – Experimental design and results for the copper removal

Run	Coded values			Actual values			Removal	
	A	B	C	A	B	C	Observed	Predicted
1	1	0	-1	1	6	10	50.66	51.13
2	1	1	0	1	10	40	52.07	52.16
3	0	0	0	0.6	6	40	37.82	37.72
4	0	1	-1	0.6	10	10	54.53	54.06
5	0	-1	1	0.6	2	70	35.08	34.01
6	-1	0	1	0.2	2	70	50.75	50.05
7	1	0	1	1	6	70	46.13	46.83
8	0	-1	-1	0.6	2	10	47.09	48.16
9	-1	-1	0	0.2	2	40	33.65	34.25
10	0	0	0	0.6	6	40	33.51	34.67
11	0	0	0	0.6	6	40	47.05	45.89
12	-1	0	-1	0.2	2	10	34.56	33.96
13	0	0	0	0.6	6	40	44.04	44.55
14	0	1	1	0.6	10	70	46.00	44.55
15	-1	1	0	0.2	10	40	42.34	44.55
16	0	0	0	0.6	6	40	44.56	44.55
17	1	-1	0	1	2	40	45.79	44.55

The coefficient of determination (R^2) presents the quality of the polynomial model [28]. The predicted R^2 considers all effects, and the adjusted R^2 considers only square effects and interaction effects between two input variables. This study's predicted R^2 and adjusted R^2 were 0.8225 and 0.9867, respectively, indicating that the model could not explain only 17.75 % of total variations. "Adeq Precision" measures the signal-to-noise ratio, and a ratio greater than four is desirable. The balance was 17.36 in this study, indicating an adequate signal. Therefore, the RSM model could be used to navigate the design space [12].

The experimental and predicted values closely match the R^2 value of 0.978 (Figure 6).

So, the high correlation coefficient (R^2=0.978) between the model and the experimental data showed that the model could efficiently predict the removal of Cr^{2+} from textile effluent using WSAC. This methodology could be successfully employed to study the importance of the test variables' individual, cumulative, and interactive effects in biosorption.

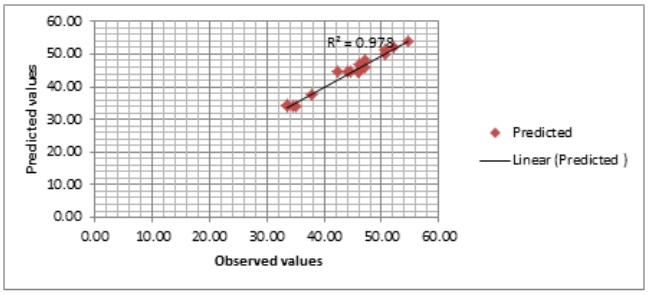


Figure 6 – Parity plot showing the distribution of experimental vs predicted values of percentage removal of Cr^{2+}

The optimum values of adsorbent dosage, pH and agitation time from BBD were found to be 0.6 g/l, six and 40 min, respectively. The maximum predicted removal of Cr^{2+} was found to be 54.06%.

The developed model equation in terms of coded factors is as follows:

$$REMOVAL = + 44.55 + 4.34*A - 2.88*B + 2.73*C + 5.89*A^2 - 1.67*B^2 - 5.68*C^2 + 3.83*A*B - 3.68*A*C - 3.09*B*C$$

where the response was the removal of chromium from textile effluent, A was the coded value of dosage of adsorbent, B was the coded value of pH of the solution, and C was agitation time.

The coefficients with one factor represent the effect on the particular factor, while the coefficients with two elements represent the interaction between the two factors. The positive sign in the equation indicates a synergistic effect, whereas the negative sign indicates an antagonistic effect.

From the analysis of variance (ANOVA) for the response surface quadratic model (Table 7), the model F-value of 34.50 implied that the RSM model is significant.

Table 7 – Analysis of variance (ANOVA) for the removal of chromium (%) with WSAC

Source	Sum of Squares	DF	Mean Squares	F-Values	P Prob > F	Comment
Model	707.13	9	78.57	34.5	< 0.0001	Significant
A	150.89	1	150.89	66.25	< 0.0001	Significant
B	66.18	1	66.18	29.05	0.001	Significant
C	59.65	1	59.65	26.19	0.0014	Significant
A^2	146.31	1	146.31	64.24	< 0.0001	Significant
B^2	11.78	1	11.78	5.17	0.0571	
C^2	135.81	1	135.81	59.63	0.0001	Significant
AB	58.55	1	58.55	25.71	0.0014	Significant
AC	54.06	1	54.06	23.73	0.0018	Significant
BC	38.11	1	38.11	16.73	0.0046	Significant
Residual	15.94	7	2.28			
Lack of Fit	7.16	3	2.39	1.09	0.4501	Not significant
Pure Error	8.78	4	2.2			
Cor Total	723.07	16				
R^2	0.978					
Adj. R^2	0.9496					
Pred. R^2	0.8225					
Adeq. Precision	17.364					
Std. Dev.	1.51					
C.V.	3.44					

The p values are used to check the significance of each of the coefficients. The p values less than 0.05 indicate that the RSM model terms are significant. In this study, A, B, C, A^2, C^2, AB, AC, BC are practical model terms. A, B, C^2 ($p<0.0001$) were the essential terms for the Chromium adsorption capacity.

The coefficient of variation (the ratio of the standard error of estimate to the mean value stated as a percentage) and F-value tests have also been carried out to assess the model's suitability.

The F-distribution is a probability distribution that compares variances by looking at their ratio. If they are equal, then the F-value would equal one. The balance of the model means square (MS) to the relevant error means the F-value represents square in the ANOVA table.

The F-value increases along with the ratio, increasing the likelihood that the model's mean square contribution will be much more significant than the error mean square. For R^2 closer to unity, the better the estimated regression equation fits the response data. The closeness of R^2 and Adj. R^2 signified that the significant terms and effects are genuinely substantial. Hence the model worked well. The agreement of Adj. R^2 and Pred. R^2 (i.e., a difference of < 0.2) authenticated that the model truly fits.

Effect of pH and dosage. pH and adsorbent dosage is the essential process parameters for assessing the removal capacity of a biosorbent. Adsorption experiments were carried out per the selected model with a ph range and WSAC dosage. The maximum removal of Cr^{2+} metal ions was 54.53% for WSAC at pH six and WSAC dosage of 0.6 g/l (Figure 7).

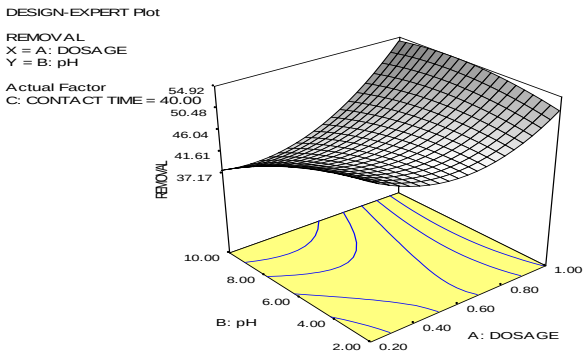


Figure 7 – A-3D interaction plot of the removal of Cr^{2+} using WSAC, the interaction of WSAC dosage and pH

Thus, with WSAC, adsorption takes place mainly in an acidic medium. Further, from the 3D graph obtained from the software, it is clear that the removal of Cr^{2+} increased at low pH values, after words, decreased with increased WSAC dosage.

Effect of contact time and dosage. The combined effect of WSAC dosage and contact time has been presented in Figure 4.8. The results show that the maximum removal was recorded at the 0.6 g/l WSAC dosage and contact time of 40 min. Further, from the 3D graph obtained from the software, it is clear that the removal of Cr^{2+} increased WSAC dosage and contact time and, afterwards, decreased with increased contact time.

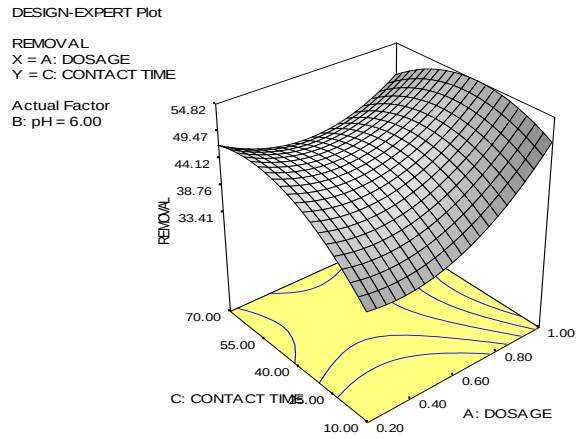


Figure 8 – A-3D interaction plot of the removal of Cr2+ using WSAC, the interaction of WSAC dosage and contact time

Effect of contact time and pH. The percentage removal of Cr^{2+} with WSAC powder was studied by a pre-selected range of time and pH values. The results are depicted in Figure 9. The results indicated that the maximum removal had occurred at a contact time of 40 min and pH of 6. Further, in the 3D graph obtained from the software, it is clear that the removal of Cr^{2+} at high contact time afterwards decreased and decreased with increased pH values.

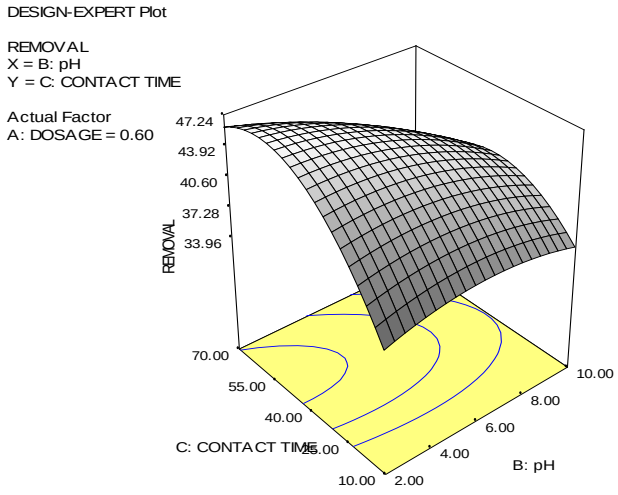


Figure 9 – A-3D interaction plot of the removal of Cr^{2+} using WSAC, the interaction of contact time and pH

CONCLUSIONS

A detailed batch experimental study was carried out for the removal of Cr^{2+} from wastewater by using Watermelon shell-activated carbon. The current study aimed to identify optimum process

conditions using response surface methodology for removing Cr^{2+} from textile effluent by WSAC as biosorbent. Response surface methodology using BBD proved a very effective and time-saving model for studying the influence of process parameters on response factors by significantly reducing the number of experiments and facilitating the optimum conditions. The Experimental values and the predicted values are in perfect match with an R^2 value of 0.978. This methodology could be successfully employed to study the importance of the test variables' individual, cumulative, and interactive effects in biosorption. The optimal removal of Cr was obtained at initial pH of 6.0 solution, WSAC dosage of 0.6 g/l and contact time of 40 min, resulting in 97.80% of the maximum predicted removal of Cr^{2+}.

FTIR results confirmed the presence of different functional groups such as phenol, alcohol, carboxylic acid, alkanes, amines, amino acids, and aromatic alkyl halide in the Watermelon. Furthermore, the SEM image showed macro, meso, and micro-pore [26], which enhanced metal uptake.

Since the studied adsorption process in removing metal from textile effluent is efficient, further studies on the use of WSAC with high fixed carbon content should be carried out to investigate the effect on removal and compared with commercial activated carbon, which has been frequently employed in the industry. Also, further studies on the use of response surface methodology (RSM-BBD) should be employed for the adsorption of heavy metals.

REFERENCES

1. Tilley, E., Ulrich, L., Lüthi, C., Reymond, Ph., Zurbrügg, C. (2016). *Compendium of Sanitation Systems and Technologies* (2nd ed.). Duebendorf: Swiss Federal Institute of Aquatic Science and Technology.
2. Mwangi, I. W., Ngila, J. C., & Okonkwo, J. O. (2012). A comparative study of modified and unmodified maize tassels for removal of selected trace metals in contaminated water. *Toxicological & Environmental Chemistry, 94*(1), 20–39. doi: 10.1080/02772248.2011.638636
3. Yu, J.-G., Zhao, X.-H., Yu, L.-Y., Jiao, F.-P., Jiang, J.-H., & Chen, X.-Q. (2013). Removal, recovery and enrichment of metals from aqueous solutions using carbon nanotubes. *Journal of Radioanalytical and Nuclear Chemistry, 299*(3), 1155–1163. doi: 10.1007/s10967-013-2818-y
4. Monachese, M., Burton, J. P., & Reid, G. (2012). Bioremediation and Tolerance of Humans to Heavy Metals through Microbial Processes: a Potential Role for Probiotics? *Applied and Environmental Microbiology, 78*(18), 6397–6404. doi: 10.1128/aem.01665-12
5. Fenta, M. M. (2014). Heavy Metals Concentration in Effluents of Textile Industry, Tikur Wuha River and Milk of Cows Watering on this Water Source, Hawassa, Southern Ethiopia. *Research Journal of Environmental Sciences, 8*(8), 422–434. doi: 10.3923/rjes.2014.422.434
6. Kannan, V., Ramesh, R., & Sasikumar, C. (2005). Study on ground water characteristics and the effects of discharged effluents from textile units at Karur District. *Journal of environmental biology*, *26*(2), 269–272.
7. Halimoon, N., & Yin, R. (2010). *Removal of Heavy Metals from Textile Wastewater using Zeolite*. Retrieved from https://www.researchgate.net/publication/289178886_Removal_of_Heavy_Metals_from_Textile_Wastewater_using_Zeolite
8. Mathur, N., Bhatnagar, P., & Bakre, P. (2005). Assessing mutagenicity of textile dyes from Pali (Rajasthan) using ames bioassay. *Applied Ecology and Environmental Research, 4*(1), 111–118.
9. WHO. (2013). *Lead poisoning and health*. Retrieved June 1, 2022, from https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health
10. Lingamdinne, L. P., Koduru, J. R., Jyothi, R. K., Chang, Y.-Y., & Yang, J.-K. (2015). Factors affect on bioremediation of Co(II) and Pb(II) ontoLonicera japonicaflowers powder. *Desalination and Water Treatment, 57*(28), 13066–13080. doi: 10.1080/19443994.2015.1055813

11. Fatima, T., Nadeem, R., Masood, A., Saeed, R., & Ashraf, M. (2013). Sorption of lead by chemically modified rice bran. *International Journal of Environmental Science and Technology, 10*(6), 1255–1264. doi: 10.1007/s13762-013-0228-x

12. Mihajlović, M. T., Lazarević, S. S., Janković-Častvan, I. M., Kovač, J., Jokić, B. M., Janaćković, D. T., & Petrović, R. D. (2014). Kinetics, thermodynamics, and structural investigations on the removal of Pb2+, Cd2+, and Zn2+ from multicomponent solutions onto natural and Fe(III)-modified zeolites. *Clean Technologies and Environmental Policy, 17*(2), 407–419. doi: 10.1007/s10098-014-0794-8

13. Wang, J., & Chen, C. (2009). Biosorbents for heavy metals removal and their future. *Biotechnology Advances, 27*(2), 195–226. doi: 10.1016/j.biotechadv.2008.11.002

14. Malik, R., Ramteke, D. S., Wate, S. R. (2006). Physico-chemical and surface characterization of adsorbent prepared from groundnut shell by ZnCl 2 activation and its ability to adsorb colour. *Indian Journal of Chemical Technology, 13*(4), 319–328.

15. Gavrilescu, M. (2004). Removal of Heavy Metals from the Environment by Biosorption. *Engineering in Life Sciences, 4*(3), 219–232. doi: 10.1002/elsc.200420026

16. Olorundare, O. F., Krause, R. W. M., Okonkwo, J. O., & Mamba, B. B. (2012). Potential application of activated carbon from maize tassel for the removal of heavy metals in water. *Physics and Chemistry of the Earth, Parts A/B/C, 50–52*, 104–110. doi: 10.1016/j.pce.2012.06.001

17. Moyo, M., & Chikazaza, L. (2013). Bioremediation of Lead(II) from Polluted Wastewaters Employing Sulphuric Acid Treated Maize Tassel Biomass. *American Journal of Analytical Chemistry, 04*(12), 689–695. doi: 10.4236/ajac.2013.412083

18. Patil, B. S., Jayaprakasha, G. K., Chidambara Murthy, K. N., & Vikram, A. (2009). Bioactive Compounds: Historical Perspectives, Opportunities, and Challenges. *Journal of Agricultural and Food Chemistry, 57*(18), 8142–8160. doi: 10.1021/jf9000132

19. Reddy, L. V., Reddy, Y. H. K., Reddy, L. P. A., & Reddy, O. V. S. (2008). Wine production by novel yeast biocatalyst prepared by immobilization on watermelon (Citrullus vulgaris) rind pieces and characterization of volatile compounds. *Process Biochemistry, 43*(7), 748–752. doi: 10.1016/j.procbio.2008.02.020

20. Mort, A., Zheng, Y., Qiu, F., Nimtz, M., & Bell-Eunice, G. (2008). Structure of xylogalacturonan fragments from watermelon cell-wall pectin. Endopolygalacturonase can accommodate a xylosyl residue on the galacturonic acid just following the hydrolysis site. *Carbohydrate Research, 343*(7), 1212–1221. doi: 10.1016/j.carres.2008.03.021

21. Idris, S., Iyaka, Y. A., Ndamitso, M. M., Mohammed, E. B., & Umar, M. T. (2012). Evaluation of Kinetic Models of Copper and Lead Uptake from Dye Wastewater by Activated Pride of Barbados Shell. *American Journal of Chemistry, 1*(2), 47–51. doi: 10.5923/j.chemistry.20110102.10

22. Ye, J., Zhang, P., Hoffmann, E., Zeng, G., Tang, Y., Dresely, J., & Liu, Y. (2014). Comparison of Response Surface Methodology and Artificial Neural Network in Optimization and Prediction of Acid Activation of Bauxsol for Phosphorus Adsorption. *Water, Air, & Soil Pollution, 225*(12). doi: 10.1007/s11270-014-2225-1

23. Kiran, B., Kaushik, A., & Kaushik, C. P. (2007). Response surface methodological approach for optimizing removal of Cr (VI) from aqueous solution using immobilized cyanobacterium. *Chemical Engineering Journal, 126*(2–3), 147–153. doi: 10.1016/j.cej.2006.09.002

24. Othman, N., Kueh, Y. S., Azizul-Rahman, F. H., & Hamdan, R. (2014). Watermelon Rind: A Potential Adsorbent for Zinc Removal. *Applied Mechanics and Materials, 680*, 146–149. doi: 10.4028/www.scientific.net/amm.680.146

25. Zarei, A., Bazrafshan, E., Khaksefidi, R., & Alizadeh, M. (2013). The Evaluation of Removal Efficiency of Phenol from Aqueous Solutions using Moringa Peregrina Tree Shell Ash. *Iranian Journal of Health Sciences, 1*(1), 65–74. doi: 10.18869/acadpub.jhs.1.1.65

26. Marsh, H., & Rodriguez-Reinoso, F. (2006). *Activated Carbon*. N. d. : Elsevier Science. doi: 10.1016/b978-0-08-044463-5.x5013-4

27. Ketcha, J., Dina, D., Ngomo, H., & Ndi, N. (2012). Preparation and Characterization of Activated Carbons Obtained from Maize Cobs by Zinc Chloride Activation. *America Chemical Science Journal, 2*(4), 136-160.

28. Zarei, M., Niaei, A., Salari, D., & Khataee, A. (2010). Application of response surface methodology for optimization of peroxi-coagulation of textile dye solution using carbon nanotube–PTFE cathode. *Journal of Hazardous Materials, 173*(1–3), 544–551. doi: 10.1016/j.jhazmat.2009.08.120

Characterisation and Treatment of Automobile and Battery Water Waste Using Coagulation and Adsorption Technique

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Abstract. Adsorption processes have seen a broad level of usage by various researchers over the years to remove heavy metals from waste streams. An adsorbent frequently used is activated carbon. Although activated carbon is used extensively in water and wastewater industries, it remains expensive. In recent years, there has been a need for economical and safe methods for heavy metal elimination from contaminated water. This need has only grown, which gave rise to research aimed toward producing low-cost alternatives to activated carbon. There is an urgent need to explore all possible sources of inexpensive agro-based adsorbents, and heavy metal removal's feasibility should be studied in great detail. This research objective is to learn how inexpensive adsorbents can remove heavy metals from wastewater. Treating Automobile battery waste efficiently remains a significant challenge due to its enormous quantity, hazardous nature, and complexity. When effective treatment technology has poor implementation, this aggravates the situation and worsens the situation further in countries with high and rising populations. This leads to more pressures of urbanisation and industrials, giving room for more industrial waste.

This research suggests the best possible options by critically reviewing the existing practices. While slow biological treatment schemes usually fail to support microbial activities in the presence of toxic components in concentrations, other physicochemical plans often need to meet strict waste disposal and discharge regulations. The approach where sludge disposal is thermally incinerated has never seen environmental justification, and this is because of dioxin release and obnoxious substances transferred directly. Newly emerging membrane-based schemes can be flexible, environmentally friendly, petite, economically self-sufficient, and easy to implement and maintain after installation.

Keywords: battery and automobile wastewater; adsorbent; carbonisation; pollution; heavy metals.

INTRODUCTION

The pollution of the environment with toxic substances has increased in recent years due to the rapid growth of industries. Most industries, such as automobile, mining, electroplating, iron–steel, and battery industries, utilise substances containing heavy metals [13]. Subsequently, these heavy metals are discharged into the environment from the effluents obtained from the industries. Although small amounts of heavy metals are necessary for the normal development of biological cycles, most are toxic at high concentrations [14]. Heavy metals being released into the environment pose a severe health threat caused by pollution to aquatic life, plants, and humans due to their persistence, non-biodegradability, and bio-accumulation in the food chain. Ground, marine, industrial, and often treated water all have heavy metals as significant pollutants. Industrial wastewater from mining, pesticides, tanneries, organic chemicals, metal processing,

pharmaceuticals, plastics and rubber, wood products, and lumber are primary point sources of heavy metal pollutants. They are easily transported by runoff water and other water sources downstream that are polluted by industrial sites. It is necessary to remove these toxic heavy metals from waste before disposal to avoid health hazards, and proper recycling plays a vital role. Heavy metal discharged wastewater is toxic, carcinogenic, and a massive threat to the health of all living organisms [26].

Large amounts of hazardous materials being released into the natural environment have resulted in various environmental problems and climate change due to their persistence and non-biodegradability. They can keep accumulating on elements such as the food chain and already have shown signs that they pose serious health challenges to humans. Therefore, removing these metals from industrial effluents is necessary to maintain environmental quality [6]. Several techniques have been used for heavy metal removal, including solvent extraction, filtration, ion exchange, coagulation, sedimentation, oxidation, and activated carbon adsorption [19]. However, these techniques have the disadvantages of high cost, low removal efficiency, and the problem of secondary contamination. Due to this, many researchers have used low-cost, environmentally friendly, and very effective and efficient adsorbents to extract and remove the metals from the effluents. These adsorbents include biomass materials, clays, charcoal, sludge ash, microorganisms, and lateritic materials, to mention a few [8]. The automobile industry (Innoson) is located in Nnewi, Anambra State, Nigeria, and was chosen due to the reasonably high metal concentration.

Environmental protection agencies have imposed stricter regulatory prohibitions to protect the environment. This has made water treatment more expensive, and complying with the discharge quality standard is becoming a massive burden for industries. Water resource pollution, mainly due to the removal of poor-quality effluents, poses a severe threat to organisms like aquatic life and humans that depend on water for sustenance. Developing countries face these challenges more where rapid population growth and industrialisation have increased the complexity of effluents. In recent years, researchers have shifted their interests to the possible reuse and recycling of various effluents, where dairy industries are no exception [5].

In most cases, these effluents are not treated and thrown into rivers, where they contribute to eutrophication by adding phosphorus and nitrogen compounds. Treating dairy effluents is of crucial importance not only for the environment but also for recycling water for industrial use. The physicochemical processes suffer the disadvantage that reagent costs are high and the soluble COD removal is low [9]. Moreover, chemical treatments could induce secondary pollution because chemical additives may contaminate the treated water. Dairy industry wastewater demonstrates a complicated system containing different components, including pollutants from the process-drawn materials, chemicals, and residues of technological additives used in individual operations. Regarding the food industry wastewater, treatment processes must ensure the required quality of discharged effluents.

Problem statement

Environmental pollution, mostly from minerals and heavy metals in wastewater, has become an enormous issue. Anthropogenic activities like mining, industrial operations, agricultural processes, and disposal of industrial waste materials have made the hazardous situation skyrocket to dangerous levels. Heavy metals like arsenic, chromium, nickel, lead, and cadmium are in industrial waste. So far, several methods have been set out for removing heavy metals, such as ion exchange, chemical precipitation, ultra-filtration, electro-dialysis, Nano-filtration, reverse osmosis, coagulation, flocculation, and many more.

However, each method has some disadvantages, like unpredictable metal ion removal, high reagent requirements, generation of toxic sludge, etc. Pollution is the biggest challenge facing the world today, and its impacts on the climate are expected to worsen if no remediation actions are taken. As the contamination of water increases, we will experience more scarcity, and this will lead to disputes over water resources. Pollution can be placed into three categories: water, land and air. Significant causes of water pollution are decomposed domestic wastes, industrial plants, and mining operations like petroleum and solid mining. Land pollution is mostly caused by industrialisation, waste dumping, and the constantly

rising human population. Air pollution is seen to arise mainly from economic and domestic activities of people like modern agriculture, thermal power stations, industrialisation, fossil fuel burning both legal, artisanal refineries and other means, and transportation which emit harmful pollutants like cars and the aviation industry.

Research shows that heavy metal ions cannot be degraded into harmless end products [15]. This makes it difficult to degrade biologically. Heavy metals contaminate our ecosystem mainly because of mining operations, refining ores, fly ash incinerators, metal plating, sludge disposal, radioactive material processes, paints, batteries, alloys, pesticides, and radioactive material processes, paints, batteries, alloys, pesticides, and preservatives [2]. Metals like Pb, Cd, Zn, and Cu, present in industrial wastewater, are non-biodegradable and exist in streams and receiving lakes, causing bioaccumulation in organisms, further leading to several health challenges or all life on earth and environmental degradation [20]. These metals enter our food chain and become difficult to track as they move up the trophic levels [24] due to the biomagnification and bioaccumulation in the food chain. They enter the living tissues and store up throughout the food chain. Humans receive the worst toxic impact since we remain at the top of the food chain [7]. Some symptoms of copper poisoning may include vomiting, jaundice, low blood pressure, and coma to death [25]. Several industries continuously release Zn (II) in their discharges [23]. Zinc toxicity through excessive ingestion may lead to several health issues, such as respiratory incapacitation and liver failure, as shown by increased respiratory activity, such as coughing, frequency of ventilation, breathing rate, and a decrease in oxygen uptake efficiency [4]. Cadmium occurs naturally in combination with zinc minerals [16]. Cadmium is hazardous and toxic as it bioaccumulates, and there exists no known homeostatic control in the human body for it. About 1-2% of ingested cadmium, when retained in the human body, is hazardous and a potent enzyme inhibitor. It has also been known to cause liver and kidney damage [16] in animals and humans.

Lead is one of the potentially toxic heavy metals and tends to accumulate in soft tissues, blood, and bones when adsorbed into the body [10]. Lead is widely used in mining, steel, automobile, batteries, and paints [22]. Lead can accumulate over a lifetime and, even at low concentration levels, may cause diseases such as anaemia, encephalopathy, vertigo, anorexia, hepatitis, and nephric syndrome [21]. Likewise, phenol is a severe environmental priority pollutant since it is toxic and harmful to organisms even at low concentrations. Phenolic compounds have been classified as high-priority pollutants by the USA EPA [12]. Besides the poisonous effects, phenolic compounds create an oxygen demand in receiving waters and impart taste and odour to water with minute concentrations of their chlorinated compounds [3]. The chronic toxicity of phenols in humans results in headaches, dizziness, fatigue, nausea, vomiting, fainting, weakness, and lack of appetite at high levels. Phenol can also change blood pressure and cause liver and kidney damage [3].

Scope of study

Waste discharge in industries, agriculture and domestic in rivers and lakes causes the deposit of pollutants in sediments. These pollutants comprise heavy metals, which pose health threats when they enter the food chain.

Incidences of heavy metal accumulation in aquatic life, like oysters, fish, mussels, sediments, and other components of marine ecosystems, have been reported worldwide. Excess amounts of heavy materials are often toxic through the direct action of the metal or their inorganic salts or organic compounds through which metals are introduced into the cell or easily detached. Metal Exposure may occur in ordinary circumstances, especially in an industrial setting, and environmental accidents can lead to high-level exposure. Even at low concentrations, some metals are toxic to aquatic organisms. The issue of metal pollution in water and marine organisms needs continuous monitoring and surveillance as these elements do not degrade and can be biomagnified in man through spread in the food chain.

Aquatic organisms are majorly affected by heavy metals present in the environment, and the level of toxicity is majorly a function of the surface water systems' water chemistry and sediment composition. Metals are mineralised by microorganisms, which are taken up by plankton and aquatic organisms. Finally, the metals now, several times

biomagnified, are taken up by man when he consumes fish from the contaminated water.

Slightly elevated metal levels in natural waters may cause the following sub-lethal effects in aquatic organisms:

- change in physiology, such as suppression of growth and development, poor swimming performance;

- change in the circulation;

- change in biochemistry, such as enzyme activity and blood chemistry;

- histological or morphological change in tissues;

- behaviour change; and change in reproduction.

Industrial by-products are available free of cost and cause significant disposal problems. Some of these wastes are regenerated, while others find no utilisation and are disposed of. If solid waste is used as low-cost adsorbents, it will reduce the volume of waste materials and the pollution problem associated with its disposal. Several industrial wastes such as red mud, metal hydroxide sludge, and fly ash have been investigated with or without treatment as low-cost adsorbents for removing pollutants from wastewater. They require little processing to increase their sorption capacity. Red mud (RM), primarily produced from the alumina industry, emerges as a residue of the digestion of bauxite ores with caustic soda for alumina (Al_2O_3) production. Inside it is fine particles of iron, titanium oxides, silica, calcium and hydroxides. These are responsible for the highly reactive surface, enabling a low-cost adsorbent to be used for heavy metal adsorption and phenols from wastewater. Hence there is a great need to extract all heavy metals from aquatic ecosystems. Research and development, therefore, focus on sector-specific methods and technologies to remove these heavy metals.

Purpose of the study

1. Using the co-activation process, characterise activated carbon from corn cob by employing chemical, physical, and chemical activation.

2. Remove heavy metals by adsorption process, which has excellent economic potential for eliminating heavy metals from Industrial waste.

3. To characterise the number of heavy metals, Chromium VI, Zinc, Copper, Lead, Iron, BOD, COD, total suspended solids, total dissolved solids and solids in most industrial waste and treatment to reduce its hazards on living things.

4. Optimising the process parameters for preparing activated carbon for effective wastewater treatment curtails environmental issues due to the discharge of untreated wastewater into water bodies and the immediate environment. It poses serious threats to both human and aquatic life.

From the study, the characterisation and treatment of industrial waste were carried out, and solid waste, BOD, heavy metals, COD, and others were eradicated from water content, thereby reducing its hazardous effects on living organisms. Besides, it can be a valuable guideline to researchers, industrial owners, and practitioners interested in improving society's health.

METHODS

Three effluent samples each were collected from Ibeto Battery industry Nnewi and Innoson Automobile company Nnewi using standard methods. Samples were collected at the point of discharge of the effluents (P1), at 20 m away from the point of effluent discharge (P2), and at 40 m away from the point of effluent discharge (P3) in a sterile bottle, labelled and preserved using standard methods.

Characterisation of wastewater. The individual and composites samples were analysed for suspended solids, total dissolved solids, Biochemical Oxygen Demand, Chemical Oxygen Demand, total solids, as well as heavy metals such as Cr (VI), Zn (II), Cu (II), Pb (II) and Fe (III) using standard methods.

Adsorbent preparation & chemical activation. Corn cobs were collected from the “Isi gate” market in Umuahia Abia State, Nigeria, and were washed with distilled water. The samples were broken into smaller sizes and then oven-dried to reduce the sample size so they could dry quickly. After oven drying and grinding, the ground sample was sieved with a 2 mm mesh size sieve at the laboratory, Civil Engineering department, MOUAU. The model was activated chemically by soaking for 2 hours in 0.5 M Hydrochloric acid. It was washed repeatedly with de-ionised water until a pH value of 7 was obtained, indicating no acid was left on the sample. The sample was air-dried for two days at room temperature.

Figure 1 – Samples soaked in 0.5 M hydrochloric acid

Figure 2 – Samples air-dried for two days

Physical activation. The ground sample was sieved with a 2 mm mesh size sieve. This was followed by carbonisation in the absence of air in a muffle furnace at a temperature of 400-600 °C for 60 minutes. The corn cob ash was washed with de-ionised water until no further impurities, such as dust or residues, were found. The corn cob ash was then air-dried for two days.

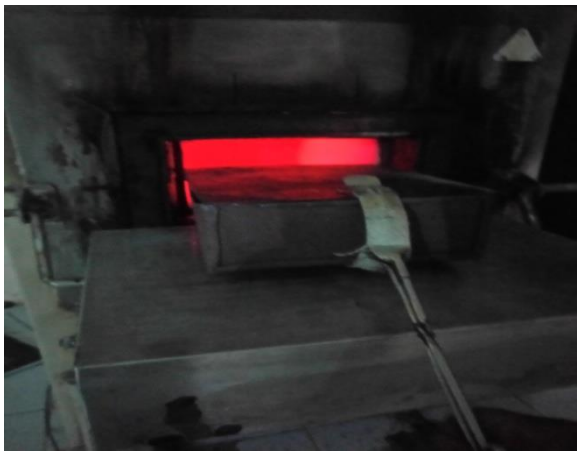

Figure 3 – Adsorbent undergoing carbonisation

Physicochemical activation. The ground sample was sieved with a 2 mm mesh size sieve. After which, it was carbonised in the absence of air in a muffle furnace at a temperature of 400–600 °C for 60 minutes. The carbonised sample was mixed with an aqueous phosphoric acid (H3P04) and soaked for 2 hours. The mixture was washed thoroughly with de-ionised water until a PH value of 7 was obtained to ensure that the acid had been thoroughly washed away. The sample was air-dried for two days.

Figure 4 – Carbonised corn cob

Characterisation of the adsorbent. The chemical compositions, including the rare earth metals for chemically, physically, and physically/chemically activated corn cobs, will be determined using standard methods.

Adsorption experiment. The chemically activated, physically activated, and physically/chemically activated corn cobs were used for the adsorption experiment. A total of three dosages, 5, 10 and 20 mg, were used.

Batch mode adsorption studies for individual metal compounds were conducted to investigate the effect of different parameters such as adsorbent particle size, contact time, temperature, initial concentration, and adsorbent dosage. The solution containing adsorbate and adsorbents was taken in 250 ml capacity conical flasks and agitated at 180 rpm in a mechanical shaker at predetermined time intervals [18]. The adsorbate was decanted and separated from the adsorbent using filter paper (Whatman No-1).

Heavy metals analysis. The final residual metal concentration after adsorption was measured using Atomic Absorption Spectrophotometer.

The following equation was used to estimate the percentage removal of heavy metals from its aqueous solution.

$$\%\text{Rem.} = \frac{Co-C}{Co} \times 100 \quad (1)$$

where C_o and C are the initial and final concentrations in the solution (mg/l), V is a known volume of wastewater (l), and m is a known mass of dry adsorbent (g).

Coagulation preparation. A stock solution of Alum was prepared before starting the experiment. The answer was prepared by dissolving 10 g of Alum in distilled water, and the solution volume will increase to 1 litre. Every 1 ml of these stock solutions was equivalent to 20 mg/l when added to 500 ml of wastewater. They were prepared in distillation water in three different concentrations (10, 20, and 30 mg/l).

Jar Test. The jar test was used to evaluate the coagulation efficiency (Alum). Jar testing is an essential tool for determining the best chemical dosing regimen and the efficiency of the treatment system [17]. A conventional jar test apparatus Was used in the experiments to coagulate the industrial wastewater using Alum. This was executed as a batch test to provide a series of six beakers with six spindle steel paddles. The pH of the solution was controlled by adding H_2SO_4 and then fractionated into the beaker containing 500 ml of suspension; the wastewater sample was mixed homogeneously. The samples were analysed for initial concentration to measure pH, TSS, COD, BOD, TS, TDS, and turbidity. After the desired amount of Alum was added to the suspension, the beakers were agitated at various mixing times and speeds, which consisted of rapid mixing (rpm) for 1 minute and slow mixing (30 rpm) for ten minutes to coagulate. After the agitation was stopped, the suspension was allowed to settle for 20 minutes. Finally, a sample was withdrawn using a pipette from the top inch of supernatant for turbidity, COD, BOD, TS, and TDS measurement, representing the final concentration. All tests were performed at an ambient temperature range of 20 to 23 °C. In the experiment, the study by varying a few experimental parameters, Alum dosage (10-30 mg/l) and pH (5.5-8.0), to know their effect on coagulation and obtain the optimum condition for each parameter.

Analytical Analysis. The COD test was performed by the wet chemical oxidation method. It was used to measure the oxygen demand for the oxidation of organic matter by strong chemical oxidation, which was equivalent to the amount of organic matter in the sample. The sample was filtered through a weighed standard glass fibre filter with 0.2 um diameter when determining TSS. The residue on the filter was dried at 100 °C. The filter's weight increases and represents the wastewater's TSS and pH.

The removal efficiency (% Removal) was calculated from (1), where C_o and C = COD, TSS and colour control of wastewater (mg/l) before and after coagulation treatment, respectively.

Matrix spiking. A Spike sample was developed, a known amount of analysis was added (a spike) to a model, and the spiked sample was tested and determined since the amount added was recovered. Two portions of the sample were prepared for testing. In the matrix spike portion, a known standard amount was added (to increase the concentration) by a known amount. The matrix spike result was higher by that amount added. A spiking solution was the standard for preparing a matrix spike. The analysed spiking solution's concentration is usually 50 to 100 times higher than that of the unspiked sample.

The spike level was chosen so that it doubled the sample concentration. The concentration of the spiking solution to use was determined. A spiking solution about 50-100 times higher than the chosen spiking level was preferred. The amount of spiking solution added was determined. The calculated volume of the spiking solution was added. Test the spiking sample using the same analytical procedure as the unspiked sample.

RESULTS AND DISCUSSION

The test results are presented in Tables 1–13 and Figures 1–10.

The selected heavy metals analysis (Tables 1–2) showed that the Lead, Chromium VI, Zinc, and Copper fall within WHO permissible limits, while iron at point 3 exceeded the allowable limits set by WHO for both battery and automobile wastewater. In the present study, Iron values ranged from 0.174 to 2.510 mg/l. These values exceeded WHO standards of 0.1 mg/l.

Table 1 – Battery wastewater heavy metals, mg/l

Selected metals	P1	P2	P3	WHO	Heavy metals to be treated
Pb	0.0081	0.0092	0.0088	0.01	-
Cr	0.015	0.007	0.003	0.05	-
Fe	0.083	0.128	0.174	0.1	P3
Zn	0.033	0.002	0.012	5	-
Cu	0.245	0.043	0.039	0.5	-

Table 2 – Automobile wastewater heavy metals, mg/l

Selected metals	P1	P2	P3	WHO	Heavy metals to be treated
Pb	0.0090	0.0077	0.0096	0.01	-
Cr	0.008	0.019	0.006	0.05	-
Fe	2.060	0.680	2.510	0.1	P3
Zn	0.006	0.034	0.016	5	-
Cu	0.074	0.168	0.102	0.5	-

Table 3 – Battery wastewater physicochemical parameters, mg/l

Parameters of interest	P1	P2	P3	WHO	Parameters to be treated
Ts	3050.00	3100.00	2970.00	500	P2
COD	83.06	1.660	1.860	255	-
BOD	12.80	6.80	3.20	10	P1
TSS	443.10	973.40	1258.30	10	P3
TDS	195.80	185.60	796.00	1000	-
Ph	0.60	0.63	0.58	6.5-8.0	P3
Turbidity (NTU)	8.158	5.816	0.745	5	P1

Table 4 – Automobile wastewater physicochemical parameters, mg/l

Parameters of interest	P1	P2	P3	WHO	Parameters to be treated
Ts	1050.00	510.00	560.00	500	P1
COD	9.09	344.50	3.00	255	P2
BOD	8.10	11.70	5.00	10	P2
TSS	256.30	275.80	314.60	10	P3
TDS	58.80	180.70	64.90	1000	-
pH	3.30	5.30	6.0	6.5-8.0	-
Turbidity(NTU)	0.750	7.183	2.263	5	P2

Table 5 – Battery wastewater (Spiked)

Selected	P3, mg/l	WHO
Pb	5.0088	0.01
Cr	5.003	0.05
Fe	5.174	0.1
Zn	5.012	5
Cu	5.039	0.5

Table 6 – Automobile wastewater (Spiked)

Selected metals	P1, mg/l	WHO
Pb	5.009	0.01
Cr	5.008	0.05
Fe	7.060	0.1
Zn	5.006	5
Cu	5.074	0.5

Table 7 – Changes in heavy metals from Battery Wastewater after adsorption using Physicochemical (Ph) and Chemical (Ch) activation from corn cob, mg/l

Heavy metals	5 mg		10 mg		20 mg		WHO
	Ph	Ch	Ph	Ch	Ph	Ch	
Pb	0.165	0.08	0.160	0.084	0.162	0.084	0.01
Zn	0.200	0.09	0.203	0.092	0.204	0.094	0.05
Fe	1.050	0.155	1.053	0.158	1.105	0.155	0.1
Cr	0.314	0.249	0.313	0.246	0.311	0.247	5
Cu	0.108	0.071	0.109	0.072	0.110	0.073	0.5

Table 8 – Changes in heavy metals from Automobile Wastewater after adsorption using Physicochemical (Ph) and Chemical (Ch) activation from corn cob, mg/l

Heavy metals	5 mg		10 mg		20 mg		WHO
	Ph	Ch	Ph	Ch	Ph	Ch	
Pb	0.105	0.055	0.109	0.058	0.108	0.052	0.01
Zn	0.150	0.315	0.153	0.318	0.154	0.319	0.05
Fe	2.218	0.100	2.220	0.103	2.224	0.104	0.1
Cr	0.052	0.059	0.0524	0.062	0.063	0.060	5
Cu	0.029	0.092	0.031	0.094	0.032	0.094	0.5

Table 9 – Changes in Battery Wastewater physicochemical parameters of interest after coagulation with Alum

Dosage	Turbidity, NTU	TSS, mg/l	TS, mg/l	pH	DO, mg/l	BOD, mg/l	COD, mg/l
5 mg	3.03	5.28	720	6.33	0.472	0.96	175
10 mg	3.64	3.51	792	6.20	0.266	0.54	149
20 mg	4.22	1.67	807	6.14	0.144	0.29	57
WHO	5	10	500	6.5-8	5	10	255

Table 10 – Changes in Automobile wastewater physicochemical parameters after coagulation with Alum

Dosage	Turbidity, NTU	TSS, mg/l	TS, mg/l	pH	DO, mg/l	BOD, mg/l	COD, mg/l
5 mg/l	2.49	9.00	352	6.17	0.472	3.80	185
10 mg/l	3.93	5.89	435	6.15	0.157	0.32	153
20 mg/l	4.11	4.71	487	6.15	0.122	2.50	91
WHO	5	10	500	6.5-8	5	10	255

Table 11 – Element Lead (Pb), %

Dosage	5 mg	10 mg	20 mg
Physicochemical (Automobile)	97.94	97.82	97.84
Chemical (Automobile)	98.40	98.84	98.96
Physicochemical (Battery)	96.70	96.80	96.76
Chemical (Battery)	98.90	98.32	98.32

Table 12 – Element Chromium VI, %

Dosage	5 mg	10 mg	20 mg
Physicochemical (Automobile)	98.96	98.85	98.74
Chemical (Automobile)	98.82	98.76	98.80
Physicochemical (Battery)	93.72	93.74	93.78
Chemical (Battery)	95.02	95.10	95.06

Table 13 – Element Iron (Fe), %

Dosage	5 mg	10 mg	20 mg
Physicochemical (Automobile)	85.12	68.85	65.50
Chemical (Automobile)	97.80	98.54	98.53
Physicochemical (Battery)	57.91	79.34	78.64
Chemical (Battery)	98.07	96.94	97.004

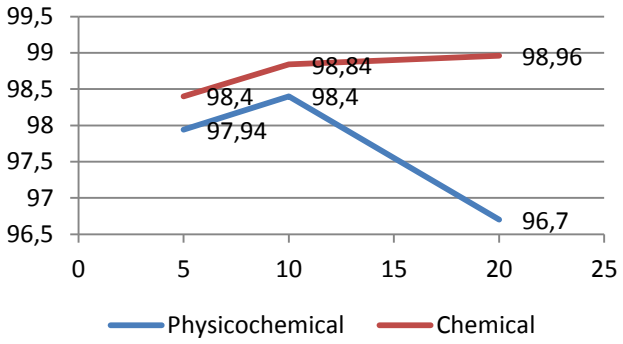

Figure 5 – A graph of percentage removal against adsorbent dosage – Physicochemical & Chemical properties for Element Lead (Pb) Automobile

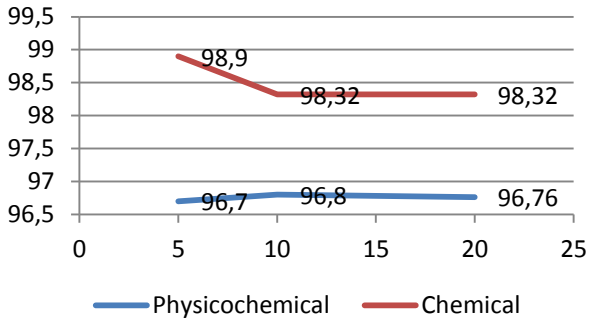

Figure 6 – A graph of percentage removal against adsorbent dosage – Physicochemical & Chemical properties for Lead (Pb) battery

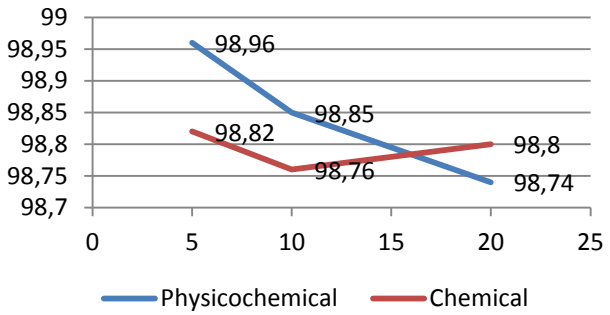

Figure 7 – A graph of percentage removal against adsorbent dosage – Physicochemical & Chemical properties for Chromium VI Automobile

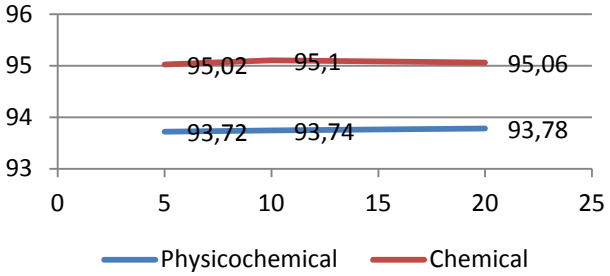

Figure 8 – A graph of percentage removal against adsorbent dosage – Physicochemical & Chemical properties for Chromium VI Battery

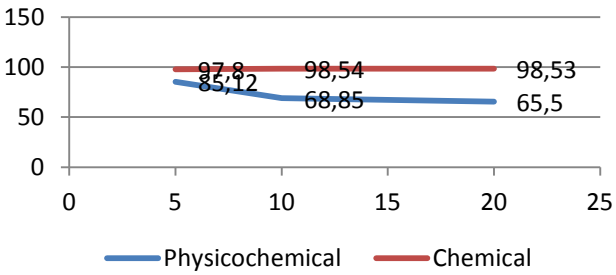

Figure 9 – A graph of percentage removal against adsorbent dosage –Physicochemical & Chemical properties for Iron (Fe) Automobile

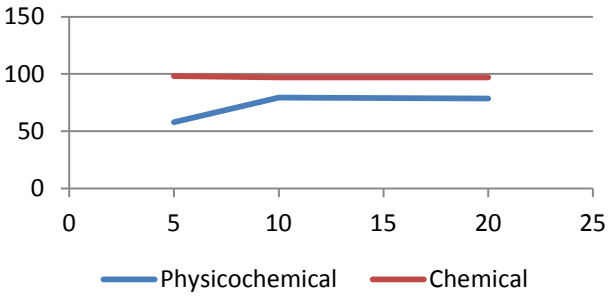

Figure 10 – A graph of percentage removal against adsorbent dosage – Physicochemical & Chemical properties for Iron (Fe) Battery

Physicochemical analysis. The physicochemical parameters result, as shown in Tables 3–4, shows that chemical oxygen demand and total dissolved solids fall within the WHO permissible limit while Total solids, Biochemical oxygen demand at point 1, total suspended solids, pH, and turbidity at point 1 and 2 exceeded the WHO permissible limit for battery wastewater sample. Total suspended solids fall within the Who permissible limit. In contrast, total solids at points 1, 2 and 3, Chemical oxygen demand at point 2, Biochemical oxygen demand at point 2, total suspended solids, pH, and turbidity at point 2 exceeded the permissible limit for Automobile wastewater.

pH Values. pH values ranged from 0.58 to 0.63 for battery wastewater and 3.30 to 6.0 for automobile wastewater which is acidic and indicated the presence of metals at a toxic level. pH is an indicator of the existence of biological life, as most thrive in a relatively narrow and critical pH range [11]. The pH of the water sample collected at points 1, 2, and 3 for the battery and automobile was below the WHO minimum allowable pH concentration for human consumption. The pH of water affects the solubility of many toxic and nutritive chemicals.

Total Suspended Solids. These are organic and inorganic solid materials which are suspended in water. It is an indicator of water pollution. Total suspended solids in the samples ranged from 443.10 to 1258.30 mg/l for battery wastewater and 256.30 to 314.60 mg/l for automobile wastewater. The values exceeded the permissible limits for WHO. The high value of total suspended solids could be due to the direct discharge of effluents into the River, which increased the River's pollution load.

Biochemical oxygen demand. BOD is the oxygen amount a bacterium requires to stabilise decomposable organic matter. A high BOD signifies the presence of a large amount of organic pollution [1]. In the present study, BOD in the sample ranged from 3.20 to 12.80 mg/l for the battery wastewater sample and 5.00 to 11.70 mg/l for the automobile wastewater sample. Points 1 and 2 for the battery and automobile wastewater samples exceed the WHO permissible limits.

Chemical oxygen demand. COD is the amount of oxygen consumed under specified conditions of organic and oxidisable inorganic matter in wastewater and water [1]. COD, ranging from 3.00 to 344.50 mg/l in an automobile

wastewater sample and 1.660 to 83.06 mg/l in a battery wastewater sample. The COD in the Battery wastewater sample is within the WHO permissible limit, while in the automobile wastewater sample at point 2, it exceeded the WHO permissible limit.

Total solids. The total solids in the wastewater sample are the residue after evaporation of the model. Ts ranged from 2970 to 3100 mg/l for battery wastewater and 510 to 1050 mg/ for automobile wastewater samples. All exceeded the WHO permissible limit.

Turbidity. Turbidity in wastewater is due to suspension, which is removable. Removal of turbidity before disinfection is essential. In the present study, turbidity ranged from 0.745 to 8.158 mg/l for the battery wastewater sample and 0.750 to 7.183 mg/l for the automobile wastewater sample. At points 1 and 2, battery wastewater exceeded the WHO permissible limit. Point 2 for automobile wastewater sample exceeded the WHO permissible limit.

Spiking. After the water analysis, the world health organisation standard was used to compare with the result obtained from the study. It was found that some heavy metals were below the average at points 1, 2, and 3. Pb, Cr, Zn, and Cu were below WHO standard, while Fe at point 3 was above WHO standard for battery and automobile wastewater.

From Tables 7–8, it was observed that Chemical Activated corn cob treat more effective as values for all the heavy metals were found to be less when added 5 mg, 10 mg, and 20 mg were in the two effluents.

CONCLUSIONS

The project illustrated how industrial wastewater, precisely automobile and battery wastewater, can be characterised and treated using coagulation and adsorption techniques. The significant parameters were heavy metals like chromium, lead, iron, copper, zinc, etc., although minor parameters were considered, such as BOD, COD, TS, TSS, Turbidity, etc. There may be other ways to achieve the same or more significant results. The beauty of this technique is that it is both economical and efficient.

The steps taken to achieve this are interesting, stimulating, and loving. The functionality value of this project makes the knowledge vital and its use in any industry for treatment. This is to end the ongoing destruction or hazards to a biological organism. Though the techniques required to perform this project seem small for the industry, the importance and result after treatment and characterisation cannot be over-emphasised, so it saves both financial commitment and resources to achieve a great result (that is, low cost against high efficiency).

Conformity with health standards, health standards, and rules were strictly followed during this analysis. This technique is restricted to be used by engineers and environmentalists who know the importance of environmental, biological, and water conditions.

Since the project has shown that using Alum as a coagulant and corn cob as an adsorbent is suitable for wastewater treatment in industries, we recommend its use in any construction, pharmaceutical, automobile, etc. industries emit wastewater involving heavy metals. Corn cob, as an adsorbent, is very sensitive to heavy metals' adsorption, so it approves its importance.

Engineers and industries do not overlook the effect of heavy metals in wastewater regarding disposal; knowing it incurs grave hazards on all living things, its damage cannot be overemphasised. The sensitisation, strict rules, and investigations in large and small industries on wastewater and its effect by health authorities such as WHO and engineering bodies should be carried out regularly to achieve environmental and biological friendliness.

REFERENCES

1. Agunwamba, J., & Nnaji, C. (2008). The oil adsorption characteristics of sphagnum peat Moss (Moss Sp). *International Journal of Research and Management Science, 1*, 111–116.
2. Ahalya, N., Kanamadi, R. D., & Ramachandra, T. V. (2005). Biosorption of chromium (VI) from aqueous solutions by the husk of Bengal gram (Cicer arientinum). *Electronic Journal of Biotechnology, 8*(3), 258–264. doi: 10.2225/vol8-issue3-fulltext-10

3. Akçay, M. (2004). Characterisation and determination of the thermodynamic and kinetic properties of p-CP adsorption onto organophilic bentonite from aqueous solution. *Journal of Colloid and Interface Science, 280*(2), 299–304. doi: 10.1016/j.jcis.2004.07.030

4. Ansari, A., Anstey, B., Doig, P., Lam, J., Wong, H., & Xu, L. (2002). *Effectivness of Some Low-Cost Sorbents for Treating Mixtures of Heavy Metals In Runoff From The First Major Storm Event After The Extended Dry Period*. Retrieved from https://www.sustain.ubc.ca/sites/sustain.ubc.ca/files/seedslibrary/465finalreportsorbents.PDF

5. Argun, M. E., Dursun, S., Ozdemir, C., & Karatas, M. (2007). Heavy metal adsorption by modified oak sawdust: Thermodynamics and kinetics. *Journal of Hazardous Materials, 141*(1), 77–85. doi: 10.1016/j.jhazmat.2006.06.095

6. Balannec, B., Vourch, M., Rabiller-Baudry, M., & Chaufer, B. (2005). Comparative study of different nanofiltration and reverse osmosis membranes for dairy effluent treatment by dead-end filtration. *Separation and Purification Technology, 42*(2), 195–200. doi: 10.1016/j.seppur.2004.07.013

7. Çelekli, A., Yavuzatmaca, M., & Bozkurt, H. (2010). An eco-friendly process: Predictive modelling of copper adsorption from aqueous solution on Spirulina platensis. *Journal of Hazardous Materials, 173*(1–3), 123–129. doi: 10.1016/j.jhazmat.2009.08.057

8. Dawodu, F. A., & Akpomie, K. G. (2014). Simultaneous adsorption of Ni(II) and Mn(II) ions from aqueous solution unto a Nigerian kaolinite clay. *Journal of Materials Research and Technology, 3*(2), 129–141. doi: 10.1016/j.jmrt.2014.03.002

9. Demirel, B., Yenigun, O., & Onay, T. T. (2005). Anaerobic treatment of dairy wastewaters: a review. *Process Biochemistry, 40*(8), 2583–2595. doi: 10.1016/j.procbio.2004.12.015

10. Duruibe, J. O., Ogwuegbu, M. D., & Egwurugwu, J. (2007). Heavy metal pollution and human biotoxic effects. *International Journal of Physical Science, 2*(5), 112–118.

11. Elhassadi, A. (2008). Pollution of water resources from industrial effluents: a case study — Benghazi, Libya. *Desalination, 222*(1–3), 286–293. doi: 10.1016/j.desal.2007.05.030

12. Environmental Protection Agency. (1984). *Methods 604: Phenols*. Retrieved from https://www.epa.gov/sites/default/files/2015-08/documents/method_604_1984.pdf

13. Friberg, L., Nordberg, G. F., & Vouk, B. (1979). *Handbook on the toxicology of metals*. North-Holland: Elsevier.

14. Gulnaz, O., Kaya, A., & Dincer, S. (2006). The reuse of dried activated sludge for adsorption of reactive dye. *Journal of Hazardous Materials, 134*(1–3), 190–196. doi: 10.1016/j.jhazmat.2005.10.050

15. Gupta, V. K., Gupta, M., & Sharma, S. (2001). Process development for the removal of lead and chromium from aqueous solutions using red mud—an aluminium industry waste. *Water Research, 35*(5), 1125–1134. doi: 10.1016/s0043-1354(00)00389-4

16. Häni, H. (1990). The Analysis of Inorganic and Organic Pollutants in Soil with Special Regard to Their Bioavailability. *International Journal of Environmental Analytical Chemistry, 39*(2), 197–208. doi: 10.1080/03067319008027697

17. Hudson, H. E., & Wagner, E. G. (1981). Conduct and uses of jar tests. *Journal (American Water Works Association), 73*(4), 218–223.

18. Krishna, D., Padma, D., Kavya Srithi, P., & Siva Prasad, P. (2014). Removal of chromium from aqueous solution by Indian Gooseberry Seed Powder as adsorbent. *Journal on Future Engineering and Technology, 9*(4), 24-31.

19. Liang, S., Guo, X., Feng, N., & Tian, Q. (2010). Isotherms, kinetics and thermodynamic studies of adsorption of Cu2+ from aqueous solutions by Mg2+/K+ type orange peel adsorbents. *Journal of Hazardous Materials, 174*(1–3), 756–762. doi: 10.1016/j.jhazmat.2009.09.116

20. Liu, D., & Huang, L. (1989). Small, but not large, unilamellar liposomes composed of dioleoylphosphatidylethanolamine and oleic acid can be stabilised by human plasma. *Biochemistry, 28*(19), 7700–7707. doi: 10.1021/bi00445a027

21. Lo, W., Chua, H., Lam, K.-H., & Bi, S.-P. (1999). A comparative investigation on the biosorption of lead by filamentous fungal biomass. *Chemosphere, 39*(15), 2723–2736. doi: 10.1016/s0045-6535(99)00206-4

22. Patterson J. W. (1985). *Industrial Wastewater Treatment Technology* (2nd ed.). Stoneham: Butterworth Publishers Stoneham.

23. Puranik, P. R., & Paknikar, K. M. (1997). Biosorption of lead and zinc from solutions using Streptoverticillium cinnamoneum waste biomass. *Journal of Biotechnology, 55*(2), 113–124. doi: 10.1016/s0168-1656(97)00067-9

24. Sankar, T. V., Zynudheen, A. A., Anandan, R., & Viswanathan Nair, P. G. (2006). Distribution of organochlorine pesticides and heavy metal residues in fish and shellfish from Calicut region, Kerala, India. *Chemosphere, 65*(4), 583–590. doi: 10.1016/j.chemosphere.2006.02.038

25. Schlatter, C. (1994). Environmental pollution and human health. *Science of The Total Environment, 143*(1), 93–101. doi: 10.1016/0048-9697(94)90535-5

26. Srivastava, V. C., Swamy, M. M., Mall, I. D., Prasad, B., & Mishra, I. M. (2006). Adsorptive removal of phenol by bagasse fly ash and activated carbon: Equilibrium, kinetics and thermodynamics. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 272(*1–2), 89–104. doi: 10.1016/j.colsurfa.2005.07.016

27. WHO. (1981). *Environmental Health Criteria 18*. Retrieved from http://www.inchem.org/documents/ehc/ehc/ehc018.htm

Effect of Wife's at First Marriage on Fertility: A Theoretical Perspective

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Abstract. This study aimed to examine the description of the effect of age at first marriage on fertility. This type of research is a literature study examining references from books, journals, articles, documents, and data from the Central Statistics Agency. The analytical technique used in this study is qualitative analysis, namely by describing the findings of data and information in the form of narratives and discussions related to the effect of age at first marriage on fertility. The results of this study indicate that the age at first marriage greatly determines fertility or the number of children. If the age at first marriage is high, the number of children will undoubtedly be higher. Therefore, the government must make more preventive and educational efforts for the productive age, especially 17 years and over, to limit the number of births. They have to mature to decide when to get married because it is related to Indonesia's increase and population growth.

Keywords: age; wife; fertility; marriage.

INTRODUCTION

The world's population reaches seven billion and will jump to nine billion in 2045. Over three-quarters of the world's population live in developing countries, Indonesia [5]. There are three main elements of Indonesia's population challenges today. First, quantity is the fourth most populous country in the world with high population growth. Second, the quality of human resources is relatively low, as reflected in the [13], which places Indonesia at 124th. Third, unequal distribution and mobility. One component that affects population growth is fertility, which increases the population [6].

Fertility is the ability to produce offspring associated with female fertility (fecundity) through marriage. Marriage is a physical and spiritual bond between a man and a woman as husband and wife to form a happy and eternal family (household). The purpose of marriage is to start a happy and lasting family. For that, husband and wife need to help and complement each other to develop their personality to support and achieve spiritual and material welfare. This law states that a marriage is valid if it is carried out according to the law of each religion and belief. Besides that, each marriage must be recorded according to the applicable laws and regulations [8].

The recording of each marriage is the same as recording important events in a person's life, such as births and deaths, that are also included in the records register. In addition, marriage has a relationship with population problems. A lower age limit for a woman to marry results in a higher birth rate. This law determines the marriage age limit for men and women, which is 19 years for men and 16 years for women. The rights and position of the wife are in balance with the rights and role of the husband both in domestic life and in association with society. So that everything in the family can be negotiated and decided jointly by husband and wife [7].

The population theory explains that the birth rate will be higher if it cannot suppress the number of young marriages. Therefore, the problem that has occurred so far is that no special regulation regulates the number of children. Another issue currently happening is related to the high

birth rate in Indonesia, so population growth is increasing. It is necessary to analyze a problem related to the causative factor of population growth, namely the age at first marriage. The birth restriction is a determinant in suppressing the growth rate and population growth. Therefore, it is necessary to regulate a regulation related to anti-natality. However, Indonesia still needs policies related to reducing the population because it is a pluralist country. There is also no legal certainty, and procedures related to limiting the number of children is only programmatic, namely through the population and family planning agency, such as the promotion of two children is enough. Efforts must be made to educate the productive age population on how they will determine the age of their first marriage [11]. The aim is to reduce the birth rate because if we analyze logically, the age at first marriage will determine the number of children to be produced.

Literature review

Basic Theory of Fertility. The term fertility is often referred to as live birth, which is the release of a baby from a woman's womb with signs of life, such as breathing, screaming, moving, heart throbbing and so on. Meanwhile, parity is the number of children a woman has. If there are no signs of life at birth, it is called still live, which in demographics is not considered a birth event.

The physiological ability of a woman to give birth or participate in reproduction is known as fecundity. The absence of this ability is called in fecundity, sterility or physiological infertility.

The analysis of fertility and the analysis of the other two demographic components, namely mortality and migration, can be grouped into three discussion sections. First, it discusses the basic concepts and measures of fertility. Second, discuss techniques for calculating fertility measures, such as CBR, ASFR, TFR, GRR, NRR, etc. Third, discussing various matters concerning the causes of fertility and its impact on multiple aspects of life.

The study of fertility stems from the discipline of sociology. Before other fields systematically discussed fertility, the sociological study of fertility had already begun [14]. For a long time, the population has been a sub-field of sociology. Most of the population analysis (besides formal demographics) is sociological analysis. By [4] have developed various theoretical frameworks on fertility behaviour which are essentially sociological. Most of the population analysis (besides formal demographics) is sociological analysis. Then, he developed different theoretical frameworks on fertility behaviour which are essentially sociological [4]. Authors [4] conducted sociological research on fertility and put forward the factors that affect fertility through what is referred to as "intermediate variables". According to [4], social, economic and cultural factors that affect fertility will be through "intermediate variables". 11 intermediate variables affect fertility, each of which is grouped into three stages of the reproductive process. Authors [4] put forward the factors that affect fertility through what is referred to as "intermediate variables". According to [4], social, economic and cultural factors that affect fertility will be through "intermediate variables". 11 intermediate variables affect fertility, each of which is grouped into three stages of the reproductive process. Authors [4] put forward the factors that affect fertility through what is referred to as "intermediate variables". According to [4], social, economic and cultural factors that affect fertility will be through "intermediate variables". 11 intermediate variables affect fertility, each of which is grouped into three stages of the reproductive process as follows:

1. Factors that affect the occurrence of sex (intercourse variables)

2. Permanent celibacy: the proportion of women who have never had sex

3. The length of the reproductive period after or between sexual intercourse:

4. Voluntary abstinence

5. Abstinence due to compulsion (by impotence, illness, temporary separation)

6. Frequency of sexual intercourse

7. Fertility or infertility affected by unintentional factors

8. Using or not using a contraceptive method:

9. Fertility or infertility affected by intentional factors (sterilization, subincision, drugs, and so

10. Fetal mortality caused by unintentional factors

11. Fetal mortality by calculated factors

According to [4], the above variables exist in all societies because each variable has its own posi-

tive and negative influence (value) on fertility. For example, if abortion is not practised, then variable number 11 is favourable for fertility. That is, fertility can increase because there are no abortions.

Fertility Determinants. One component that affects population growth is fertility, which increases the population. Fertility is the ability to produce offspring associated with female fertility (fecundity). For this reason, Indonesia must have a Grand Design for Population Development (GDPK), which includes fertility, mortality and population mobility. The desired condition is that the population grows in balance as a prerequisite for achieving a population without growth, where fertility rates and mortality rates are decreasing, and the distribution is more even. In terms of fertility, it is the achievement of a balanced population growth condition in 2015 and will continue until 2035. To achieve a balanced population growth condition (PTS), it is expected that the total birth rate (TFR) is 2, 1 per woman or net reproduction (NRR) of 1 per woman in 2015.

Family and community welfare will be easier to achieve if the number of children in the nuclear family is ideal, namely, "two children are better off", by adjusting the birth spacing and the number of children. A country's fertility level is influenced by several variables such as age, gender, marital status, use of contraceptives or other characteristics [2].

According to [4], the factors that affect fertility are intermediate variables, namely variables that directly affect and indirect variables. A country's fertility level is influenced by several variables such as age, gender, marital status, use of contraceptives or other characteristics. According to [4], the fertility rate is partly determined by background characteristics such as the perceived value of children, religion, housing conditions, education, and employment status, age at first marriage, income, and infant/child mortality. Every family has fertility norms and attitudes based on the above characteristics [1].

METHODS

This research method uses literature study type research. Data collection techniques are carried out by collecting secondary data through the library, namely journals, articles, books, and regulations and using data from the Central Statistics Agency [12]. Next, examine these references for qualitative analysis by describing the findings with narratives in the form of a discussion of how the description of the effect of age at first marriage on fertility then concludes on the findings of the data and information obtained.

RESULTS AND DISCUSSION

First Marriage Age Fertility Analysis. Age at first marriage also means at the start of the reproductive period of fertilization. The relationship between early marriage and fertility is negative. The younger the UKP, the longer the reproductive period or, the more children will be born. Age at first marriage can indicate the start of a woman's opportunity to become pregnant and give birth. Women who marry at a young age have a more extended period to get pregnant and give birth than those who marry at an older age and have more children. Based on the [12], the average age at first marriage is 18.1; ideally, it is 21 years for women and 25 years for men. One of the reasons a person's age at first marriage is high is several reasons, for example, education, mortality, work obsession and others. But in this case, what will be analyzed is related to the factors that affect the age of first marriage on fertility and how much fertility declines if the age of a person's first marriage is high.

Women's opportunities to obtain higher education are increasingly open at this time, causing many women to delay marriage. Women who spend more time on education will have shorter years of pregnancy risk because they spend many years giving birth to children in school. In addition, women with higher education tend to enter the labour market before marriage. Education can also increase women's knowledge of the information process regarding fertility choices and pregnancy behaviour [10].

In the future, more women with higher education levels will enter the labour market. In addition to the increasing number, employment requires specific skills, especially in service fields such as sales force, health, education, service, etc. The better the education level of women, the more they have the potential to make a more significant contribution to the family income so that the time they specifically devote to raising children is increasingly limited, which will affect the number of children they want. Age at first marriage is the first time a husband and wife have sex. According

to the Marriage Law, the minimum age for marriage for men is 19 years, and for women, they must be at least 16 years old. If married under the age of 21 years, it must be accompanied by the permission of the second or one of the parents or an appointed guardian.

The age of the first marriage carried out by every woman has a risk of giving birth. The younger the age at first marriage of a woman, the greater the risk faced for the safety of both mother and child. This happens because the womb of a young woman is immature to produce children or is not mentally ready for marriage. On the other hand, the older the age at first marriage, the higher the risk during pregnancy or childbirth. This happens because a woman's physical condition gets weaker towards old age. There are essential things in the age of first marriage, including:

1. Essential variables are affecting fertility. The younger a person's first marriage age, the longer the reproductive period will be. This affects the fertility rate of women and the population in general.

2. Affecting population growth rate. Due to the extended reproductive period of women who do UKPM, the possibility of these women giving birth to many children will be even greater. In macro terms, this will lead to an increase in the population growth rate of an area. Age at first marriage affects the distance between generations. The younger the age at marriage, the shorter the age gap between mother and child. Of course, there are many very influential considerations to determine when the time is right in the age of first marriage. The factors that influence the age at first marriage are:

- interpretation of religious teachings;
- level of education;
- socio-cultural situation;
- opening job opportunities for women;
- health;
- economy;
- matched pairs;
- freedom to choose a partner.

The younger a person's first marriage age, the longer the reproductive period will be. This affects the fertility rate of women and the population in general. The longer a woman's reproductive period, the more likely she is to give birth to many children. In macro terms, this will lead to an increase in the population growth rate of an area. Age at first marriage is the first time a husband and wife have sex. According to several data sources, the average age at first marriage in Indonesia is still relatively low, under 20 years. Marriage under 20 years of reproductive health can be considered too young, mentally socially unprepared, and usually not well-established economically. In general, it aims to determine the causal factors that affect the age of first marriage in Indonesia. The research method carried out in this study used a qualitative approach. Informants in this study were couples of childbearing age (EFA) and prospective EFA or adolescents.

For example, in area X, we will examine several variables that become indicators of our research, as seen in the framework below. Still, here the author only emphasizes and analyzes the effect of age at first marriage on fertility. However, there are other factors besides age at first marriage, such as education, child expenses, income and others. In this case, the writer wants to explain how age at first marriage affects fertility [9].

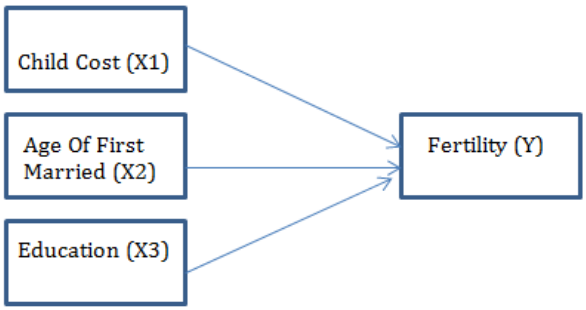

Figure 1 – Thinking Framework

Fertility is the dependent variable, while the independent variables are child costs and age at first marriage. Furthermore, various statistical tests were used to test the level of significance or the closeness of the independent variable to the dependent variable.

t-test statistics. To t-test the significance of the effect of each independent variable on the dependent variable, the t-statistical test was used at the 5% significance level.

F-test statistics. The F statistical test is used to determine whether the model is valid (validity of model).

In connection with the analytical method used in testing the hypothesis, the variable limits used in solving the problem to estimate the model are:

age of First Marriage is the respondent's age at the time of first marriage.

Characteristics of Respondents based on age at the beginning of marriage aim to determine the age of women at the time of early marriage. The age of a woman's first marriage is closely related to fertility. Because if the age of the first marriage is getting younger, the closer it is to the age of the first menstruation, the longer the reproductive period. This means a longer risk of a woman getting pregnant and giving birth. For example, based on the results of the study (Table 1), the initial age of marriage under 20 years, with a percentage of 55%, was in the first rank, while for the early age of marriage in the year 21 to 25 with a percentage of 40%. It was in the second rank and for the last grade occupied by the early age of marriage in 26-30 years with a percentage of 5%.

Table 1 – Characteristics of Respondents Based on Age at First Marriage

Age of First Marriage	Frequency	Percentage
20	55	55.00
21–25	40	40.00
26–30	5	5.00
Amount	100	100.00

Effect of Age at First Marriage on Fertility. The size regression coefficient of age at first marriage has a positive but insignificant effect on fertility, where the magnitude of the variable coefficient is 0.037. This means that for every additional year of age at first marriage, fertility decreases by 0.037, assuming other variables are constant. The statistical calculations for the variable age at first marriage (X2) obtained a t-value of 1.197 with a t-significance of 0.234. By using a significance (α) of 0.05 and a df (degree of freedom) of 93, the table value of 1.661 is obtained. Then the obtained t-count (1,197) < (1,661) indicates that the age at the beginning of marriage has no effect on fertility at the 95% confidence level.

Age at first marriage positively affects the meaning that the younger the woman is, the higher the fertility. However, the result is insignificant because the t-count is more remarkable than the t-table.

This is because the reality on the ground shows that women who marry early are not absolute. They have many children, and although a small number have 6 to 9 children, many have only 3 to 5 children. Fertility factors and socio-cultural factors also influence it. The fertility factor referred to here is a working woman who married for the first time at 14 years while she is now 32 years old with three children. This means that fertility rates tend to be low, and maybe also be because women have been influenced to use contraceptives issued by the National Family Planning Population Board. And socio-cultural factors also immensely affect the amount of fertility among poor households in the city of Makassar. Because some women tend to want to add children if they do not have a son or daughter, therefore he will stop adding children when the desired child is born.

The low age of the woman's first marriage is suspected to be due to the low level of education and financial ability, as well as the influence of socio-cultural factors. The low level of education and the family's economic capacity will encourage parents to marry off their daughters even though they are still young. Meanwhile, from a socio-cultural perspective, it generally occurs because of thoughts such as fear of their child becoming a spinster, pride if their child is quickly proposed and also wanting to reduce the burden (responsibility) as a parent if their child is married with the lowest age 14 years and the highest 28 years.

CONCLUSIONS

Based on studies that have been done that many factors affect fertility. Age at first marriage can indicate the start of a woman's opportunity to become pregnant and give birth. Women who marry at a young age have a longer time to get pregnant and give birth than those who marry at an older age and have more children. The health office needs to develop service programs for the community to help regulate fertility in the family, such as increasing access to services and providing field officers who are easily contacted by the community. Health workers should further improve socialization counselling services on reproductive rights and gender and increase productive age education programs before deciding to marry.

REFERENCES

1. Aryati, S., Yulianti, S., & Hardinasari, R. (2020). Early marriage in Yogyakarta. *E3S Web of Conferences, 200*, 04003. doi: 10.1051/e3sconf/202020004003
2. Chowdhury, A., Hoq, M., Hossain, M., & Khan, M. (2013). Factors Affecting an Age at First Marriage among Female Adolescents in Bangladesh. *Research on Humanities and Social Sciences, 3*(9),131-139.
3. Creswell, J. (2016). *Research Design: Pendekatan Kualitatif, Kuantitatif, dan Mixed*. Yogyakarta: Pustaka Pelajar (in Indonesian).
4. Davis, K., & Blake, J. (1956). Social Structure and Fertility: An Analytic Framework. *Economic Development and Cultural Change, 4*(3), 211–235.
5. Imron, A., Habibah, S. M., & Aziz, U. K. (2020). Determinant age at first marriage among women in East Java. *Jurnal Biometrika Dan Kependudukan, 9*(2), 104. doi: 10.20473/jbk.v9i2.2020.104-111
6. Nahar, M. Z., Zahangir, M. S., & Shafiqul Islam, S. M. (2013). Age at first marriage and its relation to fertility in Bangladesh. *Chinese Journal of Population Resources and Environment, 11*(3), 227–235. doi: 10.1080/10042857.2013.835539
7. Najib, N., Triwijayanti, U., & Utomo, W. (2021). Demographic Characteristics Related to First Married Age in Indonesia. *Jurnal Kesehatan Masyarakat, 17*(1), 94–101. doi: 10.15294/kemas.v17i1.26144
8. Putri, Z. D., & Nelonda, S. (2016). Socio-Economic Determinants Of Age At Firstmarriage Among Women And Early Marriage Woman In West Sumatera. *The 1st Internasional Conference on Economics, Business, and Accounting*, 465-478.
9. Roy, I., & Sarker, A. K. (2016). Early Marriage Impact on Female‟s Health and Their Satisfactory Level: A Distinctive Analytical Study in Bangladesh. *International Journal of Science and Research, 5*(3), 363–369.
10. Setiadi, S. (2021). Getting Married is a Simple Matter: Early Marriage among Indonesian Muslim Girls in Rural Areas of Java. *Jurnal Sosiologi Walisongo, 5*(2), 143–154. doi: 10.21580/jsw.2021.5.2.7970
11. Solanke, B. L. (2015). Marriage Age, Fertility Behavior, and Women's Empowerment in Nigeria. *SAGE Open, 5*(4). doi: 10.1177/2158244015617989
12. Statistics Indonesia. (2008). *Indonesia Demographic and Health Survey 2007*. Retrieved from https://dhsprogram.com/pubs/pdf/FR218/FR218%5B27August2010%5D.pdf
13. UNDP. (2022). *Human Development Report*. Retrieved from https://hdr.undp.org/
14. Windiany, E., Rahel, T. R., & Sugihanawati, A. (2022). Determinants Of Fertility Stagnation In Jakarta Province (Data Analysis Of Program Performance And Accountability Survey (SKAP) 2019). *International Journal of Nursing and Midwifery Science, 5*(3), 164–175. doi: 10.29082/ijnms/2021/vol5/iss3/372

Абревіатури у діловому дискурсі

Abbreviations in Business Discourse

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Анотація. Стаття присвячена вивченню абревіатур ділового дискурсу у структурі професійної мовленнєвої особистості бізнесмена. У статті розглядаються особливостей абревіатур на кожному рівні структури професійної мовленнєвої особистості бізнесмена. Автором розроблено та представлено структурно-морфологічну та семантичну класифікацію абревіатур ділового дискурсу, описано ключові фрейми концептуальної картини світу професійної мовленнєвої особистості бізнесмена, що вербалізуються за допомогою абревіатурних одиниць. Також продемонстровано прагмалінгвістичні особливості абревіатур ділового дискурсу.

Ключові слова: абревіатури; бізнес-дискурс; бізнес; професійна мовленнєва особистість бізнесмена; картина світу; стратегії.

Abstract. The article is devoted to studying abbreviations of business discourse in the structure of the professional speech personality of a businessman. The article deals with the features of abbreviations at each level of the structure of the professional speech personality of a businessman. The author has developed and presented the structural, morphological and semantic classification of business discourse abbreviations and described the critical frames of the conceptual picture of the world of the professional speech personality of a businessman, which is verbalized with the help of abbreviated units. The pragmalinguistic features of business discourse abbreviations are also demonstrated.

Keywords: abbreviations; business discourse; business; businessman's professional speech personality; world view; strategies.

ВСТУП

В епоху розвинених ринкових відносин та приватного підприємництва поширення та вплив бізнесу досягло колосальних масштабів та вийшло далеко за межі бізнес-спільнот. Щодня мільйони людей, які не є бізнесменами і не мають відношення до цієї сфери діяльності, з метою задоволення своїх життєво необхідних потреб змушені так чи інакше стикатися з бізнесом та взаємодіяти з ним. Як і будь-яка професійна сфера діяльності, бізнес має свої власні неповторні цілі, завдання, традиції, цінності та мотиви [1, с. 211]. Не викликає сумнівів, що для успішної взаємодії та підвищення якості комунікації суспільства з бізнесом необхідно знати, розуміти та враховувати всю специфіку професійної діяльності цього соціального інституту. Саме цей факт пояснює зростання дослідницького інтересу до вивчення ділового дискурсу та його окремих одиниць, моделювання професійної мовленнєвої особистості бізнесмена, аналізу мовленнєвого втілення цієї особистості в реальній комунікації.

Дослідження присвячене вивченню абревіатур ділового дискурсу, що з високою частотою вживаються у різних жанрах ділового дискурсу.

РЕЗУЛЬТАТИ ДОСЛІДЖЕННЯ

Дослідження щорічних звітів директорів компаній, як окремого жанру ділового дискурсу, дозволило дійти висновку про те, що абревіатури не є одиничним або випадковим явищем ділового дискурсу. Навпаки, бізнес-

мени охоче вдаються до абревіатур, як способу перетворення громіздких і незручних описів, вони легко запам'ятовуються та є незамінним засобом збереження та економії часу, наприклад: *IFRS – International Financial Reporting Standards; LTSA – Long Term Service Agreement*.

Не менш важливою особливістю вживання абревіатур у текстах річних звітів найбільших світових компаній, на наш погляд, є можливість умовного поділу абревіатур ділового дискурсу на 2 типи:

1) універсальні, тобто загальноприйняті для всіх компаній незалежно від роду діяльності (*plc – public limited company*; *AGM – annual general meeting*);

2) приватні, тобто властиві лише певній галузі, які, у свою чергу, поділяються на промислові абревіатури та оказіональні. До промислових належать абревіатури, що існують в рамках певних галузей промисловості або надання послуг і не запозичуються однією галуззю з іншої, в силу професійної специфіки (*HEETE – Highly Energy Efficient Engine, AEC – Aero Engine Controls*), а оказіональні абревіатури, характеризуються тим, що вони були створені і використовуються лише у межах їх компанії-творця (*BR 725, PWR2 Power Systems*).

Абревіатури – мовленнєві універсалії; їх номінативна функція зростає, оскільки вони дають нові назви добре відомим поняттям і предметам. Абревіатури співвідносяться зі словами, але вони не є рівнозначними, хоча у них є спільні риси. Семантична структура абревіатур схожа зі специфічними конотаціями. Контекстний рівень вивчення розкриває «приховану» семантику абревіатур [5, с. 137].

Керуючись вимогами антропоцентричного підходу, взятого за методологічну основу даного дослідження, абревіатурні одиниці ділового дискурсу розглянуто у сукупності з особливостями бізнес-діяльності та їх творцем, професійною мовленнєвою особистістю бізнесмена.

У сучасних лінгвістичних дослідженнях більшість методів моделювання мовленнєвої особистості ґрунтуються на структурі, запропонованій Ю. Карауловым [2, с. 36-39], що складається з 3 рівнів: вербально-семантичного, тезаурусного та прагматичного.

Перший рівень професійної мовленнєвої особистості бізнесмена – це вербально-семантичний, що характеризується оволодінням професійною мовою, термінологією, жаргоном, що існують у рамках сфери діяльності бізнесмена [3, с. 65]. Вивчення даного рівня передбачає аналіз усього лексичного запасу (або певного класу одиниць мови) особистості та як вона їм оперує.

Другий рівень – тезаурусний – відображає професійну картину світу (знання про професійний світ), що детермінована специфікою професійної діяльності та актуалізується у мовленнєвій діяльності особистості та особливостях сприйняття мови інших [3, с. 65]. На підставі знань про світ формується концептосфера, де ключовими концептами є *enterprise, product, market, finance*, об'єднані загальним, кореневим концептом *business*. Кожен елемент концептосфери професійної мовленнєвої особистості бізнесмена складається та розкривається за допомогою безлічі фреймів. Приміром, концепт *finance* містить у собі фрейм *money*. У рамках цього фрейму частотні абревіатури, як правило, репрезентують наступний слот - найменування кількості, наприклад: *m (million); bps (British Pound Sterling)*.

Фрейм *money* безпосередньо взаємопов'язаний із фреймом *financial operations*, який вербалізується наступними скороченнями: *ROE – Return on Equity; TSR – Total Shareholder Return*. Ще одним фреймом концепту *finance*, безпосередньо пов'язаним із *money, financial operations, finance regulating documents* є фрейм *regulating financial organizations*, який вербалізований такими абревіатурами як: *ECB – European Central Bank; ISDA – International Swap Dealers Association*.

Третій, мотиваційний рівень характеризується тим, що на цьому рівні особистість виявляє себе як повноцінний, сформований суб'єкт бізнес-діяльності, яка має набір професійних установок, цінностей, мотивів, цілей та завдань, а також поведінкових зразків, зумовлених особливостями її професійної діяльності. Іншими словами, мотиваційний рівень професійної мовленнєвої особистості бізнесмена відображає її прагматикон, який представлений у мовленнєвому втіленні за допомогою мовленнєвих стратегій та тактик [3, с. 66].

Результати дослідження свідчать, що у діловому дискурсі абревіації піддаються: 1) найменування організацій, відділів: *SFO – Serious Fraud Office; ECB – European Central Bank*; 2) найменування фінансових операцій: *PPI – Payment Protection Insurance; RoE – Return on Equity*; 3) найменування грошових валют та кількості: *bps – British Pound Sterling; bn – billion*; 4) найменування сировини, готової продукції та її властивостей: *XWB – Extra Wide Body; STOVL – Short Takeoff and Vertical Landing*.

Зі структурно-морфологічних позицій всі абревіатурні одиниці ділового дискурсу класифікуються наступним чином: ініціальні та складні. Їхньою характерною рисою є те, що вони складаються з початкових букв поняття, яке вони позначають, наприклад, *AGM – Annual General Meeting, ATG – Asia Trans Gas.* Ініціальні абревіатури поділяються на 3 підтипи: літерні, акроніми, ініціально-словесні. Зазначимо, що літерні абревіатури є найпоширенішим підтипом серед інших абревіатур ініціального типу, становлячи близько 70 %. Дана форма становить собою абревіатурні одиниці, що складаються з початкових букв описового поняття, що скорочується, і вимовляються в усній мові за алфавітним найменуванням початкових букв, наприклад: *FRC – Financial Reporting Council; RBB – Retail and Business Banking*. Найменш поширеним підтипом ініціальних абревіатур є акроніми (біля 40 %). Відмінною рисою даного підтипу є те, що абревіатури складаються з початкових букв описового поняття предмета або явища, які вимовляються разом, як повноцінне слово, наприклад: *CEO – Chief Executive Officer; STOVL – Short Take Off і Vertical Landing*. Найменш вживаним підтипом ініціальних абревіатур у структурі професійної мовленнєвої особистості бізнесмена є ініціально-словесні абревіатури. Цей підтип налічує лише 8 % і характеризується тим, що його абревіатури представлені поєднанням ініціальними літерами поняття, що скорочується, і цілого слова, наприклад: *BAMS Aircraft – Broad Area Maritime Surveillance Aircraft; UCLASS Aircraft – Unmanned Carrier Launched Airborne Surve-?llance and Strike*.

Другий тип абревіатур, що використовуються у діловому дискурсі, – складні абревіатури, які зустрічаються у діловому дискурсі порівняно з ініціальними абревіатурами нечасто, і налічують біля 2 % від загальної кількості абревіатур. Складні абревіатури утворюються шляхом усічення початкової, середньої або кінцевої частини одного слова. У текстах щорічних звітів компаній використовується лише один тип складних абревіатур-апокопи, під якими прийнято розуміти скорочені одиниці з усіченою кінцевою частиною, наприклад, *app (application); inc (incorporated)*.

Зазначимо, що будь-яка мовленнєва дія бізнесмена має бути спрямована на досягнення поставленої мети, бажаного кінцевого результату. Бізнесмен не має робити спонтанних, необдуманих дій, за якими стоїть невизначений результат. Навпаки, всі його вчинки, у тому числі і мовленнєві, мають бути скерованими та спланованими – мають враховуються всі можливі особливості ситуації та шляхи розвитку подій, а також обирається певна послідовність дій, методів та засобів. Іншими словами, будь-який бізнесмен повинен використовувати у своїй професійній діяльності певний набір мовленнєвих стратегій, які заплановано призводять до бажаного кінцевого результату. В результаті аналізу нами було виявлено такі мовленнєві стратегії:

1. Стратегія співробітництва, в рамках якої існує два підтипи: стратегія внутрішньої співпраці та стратегія зовнішньої співпраці. У мовленнєвій реалізації внутрішньої стратегії найчастішими є абревіатури, що позначають: найменування посад і звань, наприклад: *CEO – Chief Executive Officer; BSc – Bachelour of Science*; найменування відділів компанії, наприклад: *GR&D – Group Research & Development; GLT – Group Leading Team*; назви дочірніх підприємств, філій та компаній-партнерів, наприклад: *BAT Polska S. A.; Scandinavian Tobacco S. A*. Для реалізації стратегії зовнішнього співробітництва, як показує проведений нами аналіз, використовуються абревіатурні назви сторонніх організацій та компаній, а також державних установ: *IAB – International Advisory Board; FAA – Federal Aviation Agency*. Зазначимо, що, як правило, ці організації є загальновизнаними міжнародними експертними спільнотами, покликаними контролювати ведення професійної діяльності.

Вживання зазначених абревіатур у стратегії співробітництва закономірно, оскільки у робочій обстановці як у мовленні, так і у текстах звітів, договорів і ділових листів практично неможливо щоразу промовляти повні зафіксовані найменування цих установ. Крім того,

дані абревіатури підкреслюють приналежність до єдиної спільноти, близькість відносин, невимушеність та простоту звернення. Спілкування всередині одного співтовариства передбачає також поінформованість і компетентність всіх членів колективу в робочих питаннях і передбачає відсутність необхідності пояснювати ті чи інші звичайні робочі процедури, що часто проводяться, використовуючи їх повні описові найменування, замість простих і легких для запам'ятовування, розуміння і відтворення абревіатур.

У мовленнєвій реалізації стратегії співробітництва, крім вищерозглянутих груп абревіатурних одиниць, використовуються абревіатури, що позначають різні робочі процеси, сюди відносяться як фінансові, економічні та виробничі процедури, так і найменування всіляких документів, що регламентують діяльність компанії, наприклад, *IFRS – International Financial Reporting Standards; APRA – Annual Performance Related Award*.

2. Не менш актуальною є стратегія саморекламі, націлена на самопрезентацію власних переваг певного бізнесу та привернення уваги до унікальності та значущості компанії чи її товарів. Найбільш характерними абревіатурами, що беруть участь у мовленнєвій реалізації цієї стратегії є, як правило, найменування товарів компанії.

3. Стратегія домінування та маніпулювання застосовується у процесі комунікації з конкурентами. Суть її полягає у прагненні продемонструвати та переконати учасників процесу комунікації у своєму міцному фінансовому становищі, стабільній продуктивності праці, відмінній якості продукції та високій конкурентоспроможності. Традиційний спосіб довести свій успіх і стабільність – це порівняння витрат і прибутку з попередніми роками, це детальний аналіз і демонстрація конкретного результату в цифрах. У зв'язку з цим, для реалізації цієї стратегії найбільш характерним є вживання абревіатурних одиниць, що позначають різні фінансові операції, наприклад: *EPS – Earning Per Share; TSR – Total Shareholder Return*.

ВИСНОВКИ

Результати дослідження дозволяють стверджувати , що в процесі мовленнєвої реалізації стратегій ділового дискурсу абревіатури, що функціонують у них, відіграють важливу роль у досягненні бажаного результату. Говорячи про прагмалінгвістичні особливості абревіатур, була виявлена наступна закономірність: абревіатурні одиниці, що вживаються професійною мовленнєвою особистістю бізнесмена мають на меті не тільки полегшити процес сприйняття, обробки та відтворення громіздких понять і тим самим скоротити час і зусилля комунікантів, а й, залежно від мети та ситуації, вплинути на співрозмовника, переключити його увагу з менш значущих моментів спілкування на головні, підкреслити особливе ставлення і близькість спілкування, показати компетентність у певному питанні, приховати, завуалювати інформацію від непосвячених чи, навпаки, привернути увагу сторонніх.

Подальше дослідження абревіатур, що вживаються мовленнєвою особистістю в рамках своєї професійної діяльності, сприятиме збільшенню кількості знань про професійний світ, його цінності, культуру, традиції, і тим самим підвищить рівень ефективності комунікації суспільства з бізнесом.

СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ / REFERENCES

1. Cherkasova, M. (2013). Struktura professional'noj jazykovoj lichnosti biznesmena [The structure of the professional linguistic personality of a businessman]. *Vestnik Pjatigorskogo gosudarstvennogo lingvisticheskogo universiteta, 4*, 63–67 (in Russian)
2. Karaulov, Ju. (1987). *Russkij jazyk i jazykovaja lichnost'* [Russian language and language personality]. Moscow: Nauka (in Russian)
3. Shirjaeva, T., & Denislamova, D. (2014). Missija organizacii kak objekt lingvisticheskogo izuchenija (na materiale anglijskogo jazyka) [The mission of the organization as an object of linguistic study (on the material of the English language)]. *Filologicheskie nauki. Voprosy teorii i praktiki, 1*, 211–214 (in Russian)

4. Svetlichnaja, O. (2018). K voprosu ob ispol'zovanii abbreviacii v rechi [To the question of the use of abbreviation in speech]. *Studia Russica, 26*, 455–462 (in Russian)

5. Zerkina, N., Kostina, N., & Pitina, S. A. (2015). Abbreviation Semantics. *Procedia - Social and Behavioral Sciences, 199*, 137–142. doi: 10.1016/j.sbspro.2015.07.497

Лексико-семантические особенности цветообозначений в классической азербайджанской литературе (на основе литературного произведения Низами Гянджави «Семь красавиц»)

Lexical-Semantic Features of Colour Designations in Classical Azerbaijani Literature (based on the Literary Work "Seven Beauties" by Nizami Ganjavi)

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Аннотация. В статье рассматриваются лексико-семантические особенности цветообозначений на материале азербайджанского языка. Концепт цвета в языке, в частности, используется как метафорическое явление; можно утверждать, что к этимологическим особенностям цветового концепта лингвисты относятся с большим интересом. В статье отмечается, что цветовая гамма в языке тесно связано с культурным наследием народа, что находит свое отражение в произведениях восточного поэта Низами Гянджави. Ассоциация, выраженная цветом, относится к источнику происхождения конкретного цвета, который может быть, например, определенным объектом или местом. Значение, передаваемое цветом, несет символическую и эмоциональную ценность в определенном социокультурном контексте, обеспечивая контекст литературного произведения и его интерпретацию.

Ключевые слова: лингвистика; цветонаименования; азербайджанский язык; концепт; Низами Гянджеви.

Abstract. The article deals with lexico-semantic features of colour denotations in the Azerbaijani language. The concept of colour in the language, in particular, is used as a symbolic phenomenon; one can assert that linguists treat the etymological features of the colour concept with great interest. The article points out that the colour in the language is closely linked to the cultural heritage of the people, which is reflected in the works of the Asian poet Nizami Ganjavi. The association expressed by colour refers to the source of origin of a particular colour, which may be, for instance, a specific object or place. The meaning conveyed by colour carries a symbolic and emotional value in a specific socio-cultural context, providing the context for the literary work and its interpretation.

Keywords: Linguistics; colour-names; Azerbaijani language; concept; Nizami Ganjavi.

ВВЕДЕНИЕ

Азербайджанский язык имеет богатую и красочную семантическую систему, знакомство с которой позволяет понять основные типы лексических значений азербайджанских слов, их структурно-семантические подразделения. Лексика представляет собой определенную систему языковых фактов, взаимодействующих и соотносящихся друг с другом. Лексическая система находит свое выражение в разных значениях одних и тех же или разных слов. Слова, объединенные в разные смысловые группы, должны соответствовать друг другу по написанию, произношению, значению и употреблению. Смысловые группы слов в лексиконе представляют собой микросистемы – группы разных родственных слов с одинаковым корневым значением,

слова, производные от исходного слова, синонимы и антонимы.

Даже самый богатый язык не имеет лексики, способной охватить все разнообразие окружающего мира. В результате этой необходимости формируется явление полисемии, которое связано с внутренним развитием языка. То, что слова выражают полисемию в языке, в основном связано с ее переводом в переносное значение. Таким образом, когда слово употребляется в переносном смысле, из его основного значения создается новое, особое значение. По мере того, как это слово передает различные значения на основе метафоры, его значения умножаются и становятся многозначным словом. Когда слово многозначно, его первоначальное основное значение остается фиксированным.

Группу слов, обозначающих цвет (черный, синий, красный, розовый), можно также отнести к группе слов, относящихся к части речи, выражающей малое общее значение, создающее в языке многозначность. Цветонаименования в языке можно назвать могозначными лексическими единицами. «Последующие значения, сформированные по отношению к цветам, не теряют своего первоначального смысла» [6, с. 19]. Семантическая концептосфера цветонаименований включает в себя как отрицательные, так и положительные значения.

Учитывая глубокий потенциал наименований цветов в языке, мы решили проводить анализ цветообозначений в творчестве великого мирового и азербайджанского поэта Низами Гянджеви. Здесь главной задачей является анализ красочного языкового материала азербайджанского языка XII века.

МЕТОД И МАТЕРИАЛЫ ИССЛЕДОВАНИЯ

Методом исследования является описательный метод лингвистики. Отрывки из поэмы «Семь красавиц» Низами Гянджеви рассматриваются одновременно с их русским эквивалентом, что дает возможность провести сравнительный анализ языкового материала. Основным материалом исследования являются языковые материалы поэмы «Семь красавиц» Низами Гянджави.

РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЯ

Цветонаименования в языке тесно связано с культурой народа, которая является важным ментально-коммуникативным фактором. Во-первых, по мнению большинства исследователей, культура в основном выполняет коммуникативную функцию и при этом создает уникальную ментально-этническую составляющую общества, которая передается из одного поколения в другое. Культура также выполняет и идентификационную функцию по отношении определенного народа. Культура позволяет человеку чувствовать принадлежность к группе через общие ценности, символы, модели поведения и т. д. Эмоциональная связь, объединяющая членов одной группы, основана на общих ценностях.

Поскольку цвета отражают взаимодействие мышления человека и окружающей среды, проблема их исследования всегда актуальна. «Цвета отражают явление открытости языковой системы, их количество неограниченно, а другие смысловые оттенки, создаваемые цветами в выражениях, не теряют связи с их первоначальным основным значением» [6, с. 22].

В жизни человека цвета имеют большую морально-эстетическую ценность. Природа буквально создана цветами. Цвета являются и средством, удовлетворяющим потребность человека в эстетическом наслаждении, и одним из показателей, определяющих психологию человека. Цвета также обладают интересными и избранными стилистическими возможностями в литературном языке. Насчет цветов были выдвинуты различные мнения в ряде областей науки (художество, архитектура, живопись и т.д.); к ним были осуществлены подходы с различных ракурсов.

В художественном наследии азербайджанского поэта Низами Гянджеви цветы выражают определенную символику, и имеют глубокую стилистическую окраску. Четвертое большое произведение, входящее в Хамсу, состоящую из пяти поэм, известных на Востоке, называется «Семь красавиц». Герой этого произведения Бахрам шах, под влиянием одного происшествия, свидетелем которого он стал в юношестве, строит дворец, состоящий из семи куполов различных цветов, и приглашает в этот дворец семь красавиц со всего мира.

Купола окрашиваются в различные цвета, что имеет эстетически-экспрессивный смыл и особое символические значение для каждой из красавиц, описанных в поеме великого поэта. Бахрам шах сам каждый раз при посещении этих дворцов он одевается по концепту цвета. Например, красавица из Индии живет во дворце с черным куполом. Поскольку белый цвет в Индии считается цветом траура, а черный цвет имеет смысл динамичности и плодотворной земли. В данном значении наблюдается связь между этимологическим происхождением данного цвета в языках разных народов мира. Например, в поэме «Семь красавиц» Н. Гянджеви, описывая Бахрам шаха в черном одеянии, уподобляет его Аббасидам, которые являются одной из арабских династий. Из исторических источников известен тот факт, что цвет флага халифата Аббасидов был черным. «Черный флаг является одним из атрибутов этого государства, и он считался символом величия» [2, с. 22]. Одним из смыслов этого цвета является «быстрый». Поэт создал утонченную связь между этим смыслом и первым визитом Бахрам шаха в черный купол.

Во многих лингвистических исследованиях неоднократно отмечается, что в языковом уровне наименования цветов формируют достаточно сложную систему. Рассмотрев этот вопрос с позиций лингвистики можно сказать, что «каждая языковая система имеет отличительные особенности. Эти характеристики относятся к различению цветов и их оттенков, а также к тому, как они называются» [5, с. 3].

Семантический потенциал цветообозначений очень богат благодаря разнообразию информации, которую люди имеют о цвете как о многомерном явлении; цвет становится неиссякаемым источником коннотативных компонентов цветовой номинации.

В поэме «Семь красавиц» указывается, что в воскресенье Бахрам шах идет в желтый купол. В это время он не одевается в желтое, а берет в руки золотистое стекло – тем самым поэт привлекает внимание к золотистому цвету [8, с. 156; 7, с. 64].

Yekşənbə günü şah, dünya çırağı,
Qızıldan özünə verib novrağı,
Aldı Cəmşid kimi qızıl cam ələ,
Tacı günəş kimi nur saçdı elə.
Üzüyü sarı bir gültək qəşəngdi,
İşıldayan qaşı kəhrəba rəngdi.

В час, когда нагорий ворот и пола степей
Позлатились ярким блеском солнечных лучей,
В воскресенье, словно солнце поутру, Бахрам
В золотое одеянье облачился сам.
И подобен солнцу утра красотой лица,
Он вошел под свод высокий желтого дворца».

В данном отрывке поэт сравнивает корону шаха с солнцем, уподобляет его кольцо желтому цветку, даже отмечает, что лучики его сверкания осыпают землю золотистым оттенком. В этом отрывке поэт отмечает различные оттенки желтого, на азербайджанском языке употребляя такие слова как *qızıl* (золотистый), *sarı* (желтый), *kəhrəba rəngi* (янтарный цвет).

Не случайно желтый цвет иногда ассоциируется с наукой, наблюдательностью и аналитическими способностями. Возможно, это связано с его употреблением в значении мужества и фантазии. Исследования показывают, что людям, которым нравится желтый цвет, свойственна высокая склонность к творчеству, свободным, оригинальным и разным мыслителям этот цвет нравится больше. «Желтое желание, радость, близость, дружба, молодость и т.д. помимо качеств, он также считается цветом зависти и ревности. Один из оттенков цвета – мутно-желтый. Иногда его считают символом безысходности» [1, с. 51].

В своем творчестве Н. Гянджеви показывает успокаивающие свойства желтого цвета; указывает, что шафран, который очень полезен для здоровья человека, также желтого цвета [8, с. 168; 7, с. 76].

Ürək açan olur sarı hər zaman,
Halvaya təm verər ancaq zəfəran.
Zəfəran sarıdır, aldırma, burax,
Onu yeyənlərin şadlığına bax!
Sarıydı Musanm danası, əlbət,
Çox verdilər ona, odur ki, qiymət,
Sarıdır, şənliyin mayasıdır zər,
Sarı gil ən baha qiymətə gedər.

Золото нам наслажденья чистые дарит,
И халва с шафраном, словно золото, горит.
Не гляди на то, что желтый он такой – шафран!
Видишь смех, что вызывает золотой шафран?
Золото зари рассветной по душе творцу,
Поклонялись золотому некогда тельцу.
И в румийскнх и багдадских банях – только та
Глина ценится, что, словно золото, желта.

Из приведенного фрагмента видно, что поэт оценивает желтый цвет как цвет озарения и богатства, сравнивая его с золотом. Так же отмечается, что глина может быть лечебной, если имеет желтый – лечебный цвет.

Известно, что все цвета имеют как отрицательный, так и положительный смыслы. Из исторических источников известен тот факт, что древние тюрки считали желтый цвет цветом неудачи, болезни. В одном из них отмечается, что «у древних тюрков, желтый цвет считался, в основном, символом носителей плохих, вредных духов, болезней, пустых степей и пустынь, длинных, холодных зимних дней и т. д.» [3, с. 14]. Низами внес ясность в основном в положительный смысл этого цвета. Многие из цветов в природе желтого цвета, желтый цвет создает яркость среди других цветов. Золото, которое считается ценным металлом, тоже желтого цвета. Известно, что цветонаименования имеют заметную денотативную неопределенность. «Это естественно: ведь мир цвета, наши цветоощущения непрерывны, а названия цвета – дискретны. Каждое из них «покрывает» целое поле цветоощущений» [10, с. 9].

Далее в произведении Н.Гянджави «Семь красавиц» указывается, что Бахрам шах идет в зеленый купол и одевается в зеленое. В этом одеянии поэт уподобляет его райскому ангелу. Согласно религиозным верованиям в Исламе, ангелы всегда одевают зеленое и живут в зеленых садах. Зеленый является цветом жизни и процветания, цветом благоухания и мира. В поэме автор отмечает зеленый цвет, как цвет природной красоты и показывает, что этот цвет является украшением полей, озаряет глаза и представляет его как символ молодости. Вообще, зеленый считается цветом жизни и свежести. «Зеленый цвет означает безопасность и экологически безопасный» [11, с. 220]. В данном произведении зеленый цвет является цветом счастья [8, с. 126; 7, с. 40].

O günbəd ki, ona ay yol salardı,
Şahın taleyindən yaşıl çalardı.

А построенный под знаком молодой Луны,
Зелен был, как счастье шаха, как наряд весны.

При посещении красного купола Бахрам шах одевается в красное. В данном отрывке произведения поэт рассказывает о пользе красного цвета. По определению поэта красный, который является цветом крови, необходимой для жизни человека, полон положительными оттенками. Он также отмечает, что самый любимый всеми среди цветов – розы тоже красного цвета. Красный цвет – цвет любви.

Так, известно, что алый (темно-красный) цвет получали из сандалового дерева. По причине того, что аромат сандала чувствуется с наступлением утра, поэт также описал и цвет этого дерева. Он оценивает этот цвет как «душа, кровь предков». «Достаточно важную роль играет красный цвет в жизни людей на ранних ступенях развития человечества. Красный цвет у испанского народа символизировал «кровь или адское пламя». Красный цвет сигнализирует об опасности и вызывает наиболее сильную физиологическую реакцию, т. е. учащение сердцебиения и тревогу» [4, с. 18].

Низами в этой поэме красный цвет ассоциирует в основном с пламенем и считает его священным [8, с. 120; 7, с. 34].

Meyvələr, şərablar edildikcə nuş,
Daim xumarlanır, könül olur xoş.
Səndəl, ud atəşi ucalır göyə,
Tüstüsü hindlitək durur səcdəyə.
Alovdur nəşənin, keyfın dayağı,
Zərdüştün qırmızı kükürd ocağı.
O, qandır, od kimi gəlir meydana,
Ya da bir ipəkdir batmış al qana.

Яблоком без сердцевины красный уголь рдел,
В сердцевине он гранатом спелым пламенел.
Россыпью он тлел янтарной, окроплен смолой,
Жарко искрился, подернут пеплом и золой.
Чернотою раскаленной пламенел сандал,
Как тюльпаны в косах гурий, кровенел сандал.
Тюрком – но румийской крови – яркий был огонь,
Чтил народ наш от Зардушта и любил огонь.

Изображенная здесь серная печь является отсылкой к зороастрийскому священному огню. В этом и следующих куплетах поэт сравнивает сандаловое дерево и уд (алоэ) с зороастрийским огнем, запекшейся кровью, пропитанным кровью малиновым шелком, иннабом, шагарфой, покрасневшими угольками, черная сердцевина которых удалена и заменена яблоком, наполненным зернами граната, наполовину сгоревшее, наполовину

почерневшее... Сандал он уподоблял амбре, окрашенной сандаловым деревом, и солнцу, окутанному мускусом. Незажженная черная часть угля уподобляется мраку, а покрасневшая – свету, заре.

А так же красный является цветом богатство [8, с. 199; 7, с. 88].

Al təzə bəzəkdir qəlbə, əziz tut,
Hər zaman bahadır qırmızı yaqut.

Красный цвет красою блещет, коей в прочих нет,
Этим лал ценней алмаза – алый самоцвет.

В приведенных примерах видно, что красный цвет в языке поэта обозначается такими лексическими единицами как *qırmızı* (красный), *al* (алый), *zər* (блеск). Алым самоцветом поэт изображает красный рубин, тем самым символизируя красный цвет цветом богатства.

Надо отметить, что в азербайджанском фольклоре красный цвет также имеет значение управления и наказания. Если обратить внимание на азербайджанские сказки, то можно увидеть, что правитель при коронации одевается в красное. Шах, когда издает приказ о казни, тоже одевается в красное одеяние. Такой контраст цветов (положительный и отрицательный) неоднократно встречается в творчестве Н. Гянджеви.

В среду Бахрам шах направляется в бирюзовой одежде в купол того же цвета и дает определение этого цвета [8, с. 126, 7, с. 40].

Ona ki, Ütarid vermişdi nemət,
Firuzə rəngindən yetmişdi zinət".

Тот же, чьею был защитой в небе Утарид,
Бирюзой горел, как в небе Утарид горит.

В данном отрывке «бирюзовый» использовалось в смысле «синий цвет». На самом деле, «бирюза», будучи словом персидского происхождения, означает «ценный камень синего цвета» [3, с. 678]. Поэт пишет о нем как о цвете небес [8, с. 200; 7, с. 50].

Çərşənbə günündə qönçə açdı gün
Firuzə rənginə döndü göy bütün.

Бирюзы небес лазурней почва там была.
Пыль земная на густую зелень не легла.

На самом деле, каждое растение питается от солнца. Однако, подчеркивает, что синий цвет красив, потому что питается от солнца. Синий цвет – это цвет, которому уделяли внимание еще древние тюркские народы. И сегодня этот цвет сохранил свое значение как один из преобладающих цветов.

Исторически, тюркские народы оказывали чувствительное отношение к цветам. «Однако, в отличие от этих цветов, синий цвет является для тюрков не просто цветом, но и символом неба, мира и существования тюрков» [9, с. 14]. Синий цвет является одним из божественных цветов, о чем пишет Низами. В поэме поэт отмечает происхождение синего цвета, образно говоря о том, что синий цвет – это смешение несколько природных цветов в одно единое. Именно так создается цвет небес.

Герой поэта в четверг направляется в сандаловый купол. По нашему мнению, это название одноименного дерева или цвета, получаемого из него. Сандаловый цвет, т. е. коричневый цвет – это цвет плодотворной земли, деревьев, которые являются символом достатка и продолжения рода.

В пятницу он идет в белый купол. Вообще, в произведении, белый и черный цвета контактируют друг с другом. Поэт привлекает внимание тем, что первым цветом является черный, а последним – белый. Так, Бахрам шах сначала отправляется в черный купол, а в конце – в белый. В части произведения «Визит Бахрама в пятницу в белый купол и рассказ дочери падишаха седьмой страны» [8, 244–261], комнаты белеют от лучей солнца, также шах одевается в белое и идет на встречу с седьмой красавицей.

В произведении, «черный» выступает символом ночи, а «белый» - утра. В черном одеянии Бахрам шах отправился к первой красавице ночью, тогда как в белом одеянии встречается с красавицей утром [8, с. 126; 7, с. 41].

Keyvan taleyində günbəd ki, vardı,
Qaraya bürünmüş müşkə oxşardı".

Он в субботу, в день Кейвана, в черный шел дворец,
Как ему по гороскопу предсказал мудрец.

В жизни белый и черный цвета являются чаще всего используемыми цветами. Как и все цвета, «черный» и «белый» имеют противоположные свойства. На самом деле, специалисты указывают, что нет цвета под названием «черный». Черным считается цвет, поглощающий и уничтожающий свет. Согласно ряду древних и современных подходов, черный цвет выражает и напоминает грусть, одиночество и тоску, беспокойство. Его также называют «траурным» цветом [8, с. 155; 7, с. 43].

Çəkdim o qədər ki, qəmdən ahü-zar,
Qismətim kəsildi bu qara paltar.
Qara ipək gətir". O, durdu, getdi,
Qaranlıq gecədə tədarük etdi.
O qara paltarı alıb geyincə,
Hazırlıq görərək mən haman gecə
Məmləkətim deyə yola düzəldim,
Qaralar içində evimə gəldim.
Qara geyənlərə şaham, sərdaram,
Qara bulud kimi coşub gurlaram.

От расспросов наших долгих получился толк.
Вот что гостья рассказала: «Этот черный шелк
Смысл таит, имеет повесть чудную свою,
Вы узнать ее хотите? Что ж, не утаю,
А от вас расспросов многих я сама ждала..,
Я невольницею царской некогда была.
Этот царь был многовластен, справедлив, умен;
В памяти моей живет он – хоть и умер он.

Надо отметить, что черный цвет в тюркских языках цвет помимо печали изначально символизировал величие и могущество. Например, в выражении *qara dağlar* (буквальное значение – черные горы) отмечается величие гор, а не цвет. Исходя из этого, можно утверждать, что данная лексическая единица имела смысл «величественный, большой, громадный». Значимость печали и грусти, а также злости у него сформировалось в позднем этапе развития языка.

Основная семантическая характеристика антонимов в цветовой парадигме состоит в том, что они отражают определенную степень контрастности, основанную на их принадлежности к разным категориям. Противоречие белого и черного не раз можно встретить в произведениях Низами. Например [8, с. 56; 7, с. 6].

Havayla yekrənglik həvəsi vardı,
O gah qaralardı, gah ağarardı.
Gözəl imarəti yetirdi başa,
Gün ondan nur içdi o gündən bəri.

Тень от пролетающего облачка падет –
Снежно-белым делается весь дворцовый свод.
Цвета неба – он миражем в воздухе висел,
То румийцем белым был он, то, как зинджь, чернел.

По причине выражения пессимизма, в некоторых странах мира в детских комнатах не используется черный цвет. С одной стороны, этот цвет выражает силу, могущество и значимость. Следует отметить, что в некоторых культурах черная краска считалась лечебной. «Например, в Древнем Египте сурьмой красили веки, чтобы защитить их от болезней» [12, с. 73]. Сурьма – органическая черная подводка для глаз, которая до сих пор используется женщинами востока. Считается, что сурьма имеет лечебные свойства и при ее использовании глаза не теряют острое зрение.

Любители черного цвета бывают самонадеянными, упорными и решительными. Они умеют принимать независимые решения и добиваться успеха. Существует также утверждение, что черный цвет предпочитают люди с определенными комплексами.

Однако, в произведениях Низами черный цвет выступает как эталон красоты, если это касается цвета глаз или волос [8, с. 170; 7, с. 60].

Yellənən o qara qıvrım tellərin
İçində gül üzü o şux dilbərin,
Laçın qanadmın altında duran
Həvasil quşuna bənzərdi, inan.

С опьяненьем вспыхнул в сердце и любовный пыл
Я рукою черный локон, как канат, схватил.
Дивы похоти с каната снова сорвались,
Бесноватого канатом связывать взялись.

В модальном значении цвета считаются несущими набор возможностей, из которых можно выбрать значение в соответствии с коммуникативными потребностями и интересами определенного контекста.

ВЫВОДЫ

Можно утверждать, что символы одного и того же цвета в разных культурах символизируются по-разному. Например, красный цвет, который во многих культура считается цветом агрессии и войны, в произведении Н. Гянджеви представляется как цвет богатства и роскоши. Таким образом, в семантическом ярусе цветообозначений наблюдается сверхпотенциальное расхождение.

Подобные противоречия в семантике цветообозначений встречаются в поэтическом языке. В ряде литературных образцов азербайджанского народа можно встретить своеобразные стилистические моменты. Это является одним из вопросов, связанных с метафорами в литературном языке.

Ассоциация, выраженная цветом, относится к источнику происхождения конкретного цвета, которым может быть определенный объект или даже место. Значение, передаваемое цветом, несет символическую и эмоциональную ценность в определенном социокультурном контексте, обеспечивая контекст произведения и его интерпретацию.

СПИСОК ИСПОЛЬЗОВАННЫХ ИСТОЧНИКОВ / REFERENCES

1. Abdullabayova, P. (2022). Zalimkhan Jaqubun poezijasynda sary rangin uslub chalarlary [Stylistic shades of yellow color in the poetry of Zalimkhan Yagub]. *Azarbajdzhan dili va adabijjat tadrisi, 1*, 47–54 (in Azerbaijani).
2. Abdullabayova, P. (2021). Leksiko-semanticheskie osobennosti cvetooboznachenij v azerbajdzhanskom literaturnom jazyke [Lexical-semantic features of color markings in the Azerbaijani literary language]. *Slovak International Scientific Journal, 57*, 21–23 (in Russian).
3. Mammadov, H. (1985). *Arab va fars sozlari luga'ti* [Dictionary of arabian and persian words]. Baku: Yazychy (in Azerbaijani).
4. Azizova, S. (2018). Simvolicheskaja osobennost' cveta v frazeologizmah ispanskogo jazyka [The symbolic peculiarity of the color in the phraseology of the Spanish language]. *Elmi ish, 1*, 17–18 (in Russian).
5. Dzhabarova, A. (2015). Mukhtalifsistamli dillarda rang adlarynyn semantik-struktur khususijjatlari (alman və Azarbajdzhan dillarinin materiallary asasynda) [Semantic-structural features of color names in languages with different systems (based on materials from German and Azerbaijani languages)] (Doctoral thesis). Baku (in Azerbaijani).
6. Dhzahangirli, Z. (2019). İngilis dilchiliyinda rang bildiran sozlarin tahlili masalalari [Problems of analysis of words denoting color in English linguistics]. *Humanitar elmlarin oyranilmasinin aktual problemlari, 2*, 19–23 (in Azerbaijani).
7. Gandzhavi, N. (1986). *Sem' krasavits* [Seven beauties]. Moscow: Khudozhestvennaja literatura (in Russian).
8. Gandzhavi, N. (2004). *Yeddi gozel* [Seven beauties]. Baku: Lider Press (in Azerbaijani).
9. Medetog'lu, A. (2013, February 24). Türklerde renkler ve renk anlamları [Colors and color meanings in Turks]. *Turkistan*. (in Turkish).
10. Mustafaeva, K. (2018). *Semanticheskaja struktura i simvolicheskoe znachenie cvetooboznachenij v eposah "Kitabi-Dede Korkud" i "Beovul'f"* [Semantic structure and symbolic meaning of color symbols in the epics "Kitabi-Dede Korkud" and "Beowulf"] (Doctoral dissertation). Baku (in Russian).
11. Pejhua, U. (2022). Semantika cvetooboznachenij zelenyj v kitajskoj i russkoj lingvokul'turah [Semantics of color-coded green in Chinese and Russian linguistic cultures]. *Nauchnye izvestija, 29*, 218–222 (in Russian).
12. Yuryev, A., Mogilevskaya, N., & Myrzabayeva, Zh. (2018). Color naming in myths and beliefs of the ancient world. *Science and World, 3*(5), 71–74.