European Science Review

2025, No 7–8

PREMIER Publishing

Vienna
2025

European Science Review

Scientific journal

2025, No 7–8

ISSN 2310-5577

Proofreading Kristin Theissen

Cover design Andreas Vogel

Additional design Stephan Friedman

Editorial office Premier Publishing Praha 8
Karlín, Lyčkovo nám. 508/7, PSČ 18600

Email: pub@ppublishing.org

Homepage: ppublishing.org

European Science Review an international, English language, peer-reviewed journal. The journal is published in electronic form.

The decisive criterion for accepting a manuscript for publication is scientific quality. All research articles published in this journal have undergone a rigorous peer review. Based on initial screening by the editors, each paper is anonymized and reviewed by at least two anonymous referees. Recommending the articles for publishing, the reviewers confirm that in their opinion the submitted article contains important or new scientific results.

Premier Publishing s.r.o. is not responsible for the stylistic content of the article. The responsibility for the stylistic content lies on an author of an article.

Instructions for authors

Full instructions for manuscript preparation and submission can be found through the Premier Publishing s.r.o. home page at: http://ppublishing.org

Material disclaimer

The opinions expressed in the conference proceedings do not necessarily reflect those of the Premier Publishing s.r.o., the editor, the editorial board, or the organization to which the authors are affiliated. Premier Publishing s.r.o. is not responsible for the stylistic content of the article. The responsibility for the stylistic content lies on an author of an article.

Included to the open access repositories:

The jurnal has Index Copernicus Value (ICV) 92.08 for 2022.

SJIF 2024 = 6.735 (Scientific Journal Impact Factor Value for 2024).

European Science Review 2025,
No 7-8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 1. Chemistry

DOI:10.29013/ESR-25-7.8-3-14

STUDY ON THE PHOSPHORUS REMOVAL MECHANISM AND APPLICATION POTENTIAL OF FE/N-MODIFIED BIOCHAR

Yiming Gao [1]

[1] Lower Merion High School, United States

Cite: *Yiming Gao (2025). Study on the Phosphorus Removal Mechanism and Application Potential of Fe/N-modified biochar. European Science Review 2025, No 7–8.* https://doi.org/10.29013/ESR-25-7.8-3-14

Abstract

Phosphorus is a key nutrient limiting the primary productivity of lakes, but its excessive input has become the main cause of eutrophication. To address both phosphorus pollution in water bodies and the need for resource recovery, this paper developed an iron-nitrogen co-modified biochar (Fe/N-BC) using agricultural wastes as the raw material. The modified biochar was produced through the co-pyrolysis of $FeCl_3$ and urea and achieved improvements in both structure and function. Its structure was characterized using BET and FTIR techniques. Its phosphate removal performance and adsorption behavior were investigated through batch adsorption experiments and were analyzed by kinetic and isothermal models, respectively. The results showed that Fe/N-BC possessed a high specific surface area (916.5 m^2/g) and a well-developed microporous structure, with a maximum phosphorus adsorption capacity of 31.34 mg/g, which outperformed that of raw biochar and attapulgite (a control material). The adsorption process conforms to a pseudo-second-order kinetic model, indicating chemisorption as the dominant mechanism. FTIR analysis revealed the formation of Fe–O–P bonds and hydrogen bonding interactions involving pyrrolic-N, showing a synergistic adsorption system. At pH 5 and with coexisting Cl/SO_4^{2-} ions, Fe/N-BC still showed good adaptability and resistance to interference. Furthermore, in actual lake water, the material maintained stable phosphorus removal performance, proving its strong environmental adaptability and potential for engineering applications. The Fe/N co-modification in this study strategy helps deepen the understanding of phosphorus adsorption and build a practical foundation for creating more effective materials to control eutrophication in water bodies.

Keywords: *Phosphorus removal; Biochar; Fe/N co-modification; Adsorption mechanism; Eutrophication control*

1. Introduction

Phosphorus (P) is a key limiting nutrient for primary productivity in lake ecosystems and plays a vital role in the growth and metabolism of aquatic organisms. However, when excessive amounts of phosphorus enter the

water, it can lead to eutrophication (Qian et al., 2023). The sources of excessive P include point sources such as industrial discharges and municipal wastewater, and non-point sources like agricultural runoff (Luo et al., 2023). According to the United Nations Environment Programme (UNEP), eutrophication can lead to dissolved oxygen depletion, loss of biodiversity, and threats to drinking water safety. Therefore, it is important to develop effective and sustainable phosphorus removal and recovery strategies.

There are different techniques for phosphorus removal from water bodies. Biological methods involve polyphosphorus bacteria taking up phosphorus aerobically and releasing it anaerobically, and through sludge discharge, phosphorus absorbed by microorganisms is removed from the system (Pan et al., 2024). However, this process requires precisely controlled environmental conditions (Zubrowska-Sudol & Walczak, 2015). Physicochemical methods mainly include chemical processes and adsorption. Chemical processes can remove phosphorus effectively, but they also require large quantities of reagents, have high sludge production, and potentially produce secondary pollution (Pan et al., 2024). In contrast, adsorption is considered a promising technique for its low cost, high removal efficiency, easy operation, absence of secondary pollution (Mei et al., 2021), and wide applications across different treatment conditions (Cheng et al., 2023).

Biochar is produced from biomass through pyrolysis. It is a suitable adsorbent for phosphorus because it has a high specific surface area, well-developed porosity, and rich functional groups (Lin et al., 2024), and can support carbon neutrality goals (Li et al., 2022). Among biochar modification techniques, Fe modification provides functional groups and generates pore structures, making it one of the most widely used methods (Yi et al., 2021). Still, Fe modification alone produces an insufficient number of functional groups (Li & Shi, 2022). According to Liu et al. 2020, the N-doping method added more nitrogen-containing functional groups like pyridinic N and pyrrolic N. The electron pairs of nitrogen functional groups can also facilitate electron exchange in adsorption processes (Zhou et al., 2018) and thus improve electron transfer. Consequently, this study presents an iron and nitrogen co-modified biochar (Fe/N-BC) with rice straw as the raw material. This biochar was produced through one-step pyrolysis of rice straw pre-treated with $FeCl_3$ and urea to improve the phosphate adsorption efficiency. Fe–N co-modification improved biochar's properties by increasing surface area, creating more pore structure and functional groups, introducing magnetic components, and improving hydrophilicity and polarity (Mei et al., 2021). Moreover, rice straw biochar can help mitigate the issue of over 100 million tonnes burned directly and reduce greenhouse gas emissions, and serve as a soil amendment and a slow-release fertilizer because of its high porosity, large surface area, and high cation exchange capacity (CEC) (Singh et al., 2025).

Currently, few studies have examined Fe-N-modified biochar as an adsorbent or investigated how this co-modification alters its physicochemical properties (Mei et al., 2021). This study analyzed Fe/N-BC's phosphate adsorption behavior and structure characteristics through kinetics and isothermal models, and FTIR analysis of Fe/N synergistic mechanisms. Also, this study investigated the effects of varying pH, coexisting ions (like Cl^-, $SO4^{2-}$), and ion strength on adsorption behavior; Eventually, phosphorus removal experiments were conducted using actual water samples to evaluate the material's environmental adaptability and application prospects. Moreover, this study selected attapulgite, a natural clay mineral, as a comparison material to assess Fe/N-BC's adsorption performance. The study results proved that Fe–N co-modification is an effective method to improve the biochar's adsorption performance on phosphorus. This study aims to provide a scientific foundation for developing effective phosphate adsorbents to control lake eutrophication and achieve sustainable phosphorus resource management.

2. Materials and methods

2.1 Preparation of adsorption materials

Three adsorption materials were used in this study, including raw rice straw biochar, iron-nitrogen modified rice straw biochar, and attapulgite clay.

Raw Rice Straw Biochar (RSBC**):** 10 g of rice straw mixed with deionized water and

stirred on a magnetic stirrer for 24 hours. After centrifugation, the solid was dried in an oven at 80 °C. The dried samples were then placed in a quartz boat and pyrolyzed in a tube muffle furnace (OTF-1200X-S). The heating rate was set to 5 °C/min, and the temperature was held at 700 °C for 2 hours before cooling to room temperature. The resulting solid was washed with deionized water until nearly neutral, dried again, and ground using a ball mill. The final product was sieved through a 100-mesh screen to obtain uniform raw rice straw biochar.

Iron/Nitrogen Co-Modified Rice Straw Biochar: 10 g of rice straw, 50 g of $FeCl_3 \cdot 6H_2O$, and 12 g of urea were dissolved in 200 mL of deionized water. The mixture was stirred on a magnetic stirrer for 24 hours, then centrifuged and dried in an oven at 80 °C. The dried solid was subsequently pyrolyzed, washed, ground, and passed through a 100-mesh sieve to obtain uniform Fe/N-modified rice straw biochar.

Attapulgite: The attapulgite used in this study was sourced from Mingguang City, Anhui Province, China. It was obtained by grinding natural attapulgite clay and sieving it through a 100-mesh screen.

2.2 Phosphate Adsorption Kinetics

Accurately weigh approximately 0.20 g of the adsorbent material into a centrifuge tube and add 500 mL of phosphate solution at a concentration of 30 mg/L. Place the mixture at 25 °C and perform constant-temperature shaking. Sample for 0, 5, 10, 20, 30 minutes and 1, 2, 3, 4, 6, 8, 10, 12, and 24 hours, then filter the solution through a 0.45 μm membrane to determine the phosphate concentration in the filtrate.

The phosphorus adsorption kinetics processes of different materials were fitted using pseudo-first-order and pseudo-second-order adsorption kinetics models, and the calculation formulas were Formula (1) and Formula (2), respectively:

$$\ln\left(q_e - q_t\right) = \ln q_e - k_1 t \quad (1)$$

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

where q_t represents the amount of phosphate adsorbed by each material at time t (mg/g), q_e is the adsorption capacity of each material at equilibrium (mg/g), k_1 is the adsorption rate constant in the pseudo-first-order kinetic model, and k_2 is the adsorption rate constant in the pseudo-second-order kinetic model.

2.3 Phosphate Adsorption Isotherms

Weigh 0.030 g of the adsorbent material into a centrifuge tube and separately add 200 mL of phosphate solutions (KH_2PO_4) with concentrations of 10, 30, 50, 100, 150, 200, 500, and 1000 mg/L. Shake the mixture at 25 °C for 24 hours at a constant temperature, then filter through a 0.45 μm membrane. The phosphate concentration in the filtrates is then measured.

The phosphate adsorption isotherms of five materials were fitted using Freundlich and Langmuir isotherm models. The corresponding equations are:

$$q_e = K_F C_e^{1/n} \quad (3)$$

$$\frac{C_e}{q_e} = \frac{1}{q_{max} K_L} + \frac{C_e}{q_{max}} \quad (4)$$

where *qe* is the amount of phosphate adsorbed by each material at equilibrium (mg/g), q_{max} represents the maximum adsorption capacity of each material (mg/g), *KL* is the Langmuir constant, *KF* is the Freundlich constant, n indicates the adsorption intensity, and *Ce* is the equilibrium concentration of phosphate in the solution.

2.4 Influencing Factors

2.4.1 Influence of pH

To investigate the effect of pH value on the phosphorus adsorption efficiency of different materials, HCl and NaOH were used to adjust the initial pH values of the solution to 5, 6, 7, 8, 9, and 10, respectively, with an ion strength of 0.1 mM. The remaining steps follow those described in Section 2.3.

2.4.2 Type of Coexisting Ions

Add 0.030 g of dried adsorbent material to a centrifuge tube and set the initial phosphate concentration to 40 mg/L. Choose F^-, Cl^-, SO_4^{2-}, CO_3^{2-}, K^+ and Ca^{2+} as co-existing ions, each at a concentration of 0.1 mm. The remaining steps follow those described in Section 2.3.

2.4.3 Ionic Strength

Weigh approximately 0.030 g of each adsorbent material into centrifuge tubes and

control the initial phosphate concentration at 40 mg/L. Adjust the ionic strength for each set in a range of 0 to 0.2 mM. The remaining steps follow those described in Section 2.3.

2.5 Application to Phosphate Removal in Actual Water Bodies

To further verify the phosphate removal performance of raw biochar, attapulgite, and Fe/N-modified biochar in real water bodies, representative samples were collected from urban rivers and lakes. Phosphate concentrations in the water samples were measured before and after adsorption. After filtration through a 0.45 μm membrane to remove suspended particulate matter, 100 mL of each river or lake sample was mixed with 15 mg of the corresponding adsorbent. The mixtures were shaken at room temperature for 4 h and then filtered again through a 0.45 μm membrane. Phosphate removal efficiency was calculated based on concentration differences before and after adsorption.

3. Results and Discussion

3.1 Material Characteristics and Pore Structure

The specific surface area of the iron/nitrogen co-modified biochar (Fe/N-BC) reached 916.5 m²/g, which is 6.8 times greater than that of unmodified biochar (133.8 m²/g) (Table 1). These results indicate that the co-pyrolysis of $FeCl_3$ and urea significantly enhanced pore development. During pyrolysis at 700 °C, the molten salt effect of $FeCl_3$ and NH_3 released from urea decomposition worked together to accelerate the gasification reaction of the carbon matrix and formed a microporous-mesoporous hierarchical structure (microporous volume of 0.66 cm³/g, total pore volume of 0.94 cm³/g). This result is consistent with the synergistic pore-making effect of HNO_3 oxidation and Fe^{2+} loading (Li et al., 2020). In contrast, the attapulgite material (147.5 m²/g) showed weak pore development due to the limitation of the silicate mineral crystal structure, with a relatively low total pore volume 0.085 cm³/g. Clearly, the iron-nitrogen co-modification strategy effectively overcomes the agglomeration effect of conventional iron-based biochar, and its specific surface area far exceeds that of Fe-BC (10––12.5 m²/g) (Li B. et al., 2021).

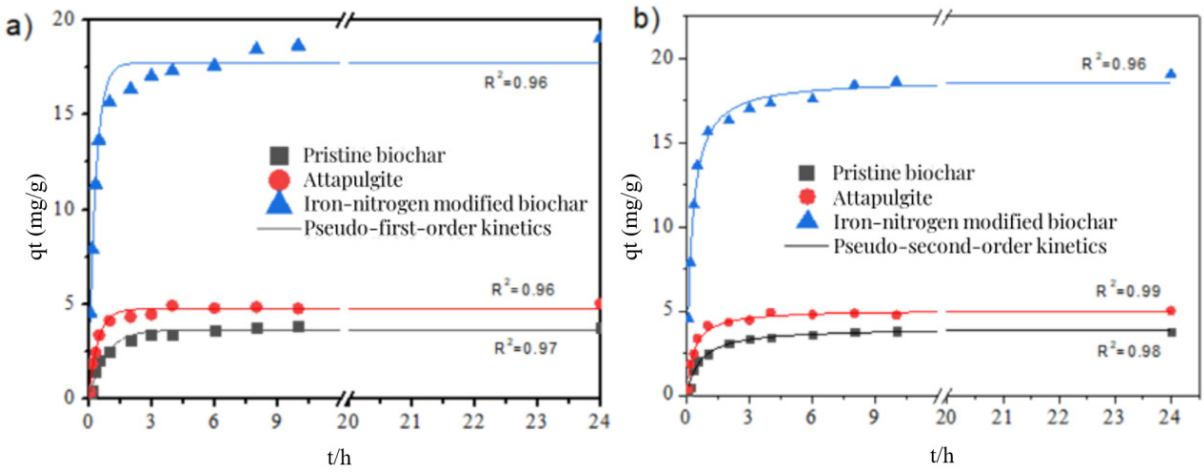
Table 1. *Comparison of Specific Surface Area and Pore Characteristics of Different Materials*

Index	Pristine biochar	Iron-nitrogen-modified biochar	Attapulgite
Specific surface area ($m^2 \cdot g^{-1}$)	133.8	916.5	147.5
Total pore volume ($cm^3 \cdot g^{-1}$)	0.086	0.94	0.085
Micropore volume ($cm^3 \cdot g^{-1}$)	0.052	0.66	0.058
Micropore porosity (%)	60.4	70.2	68.2

3.2 Phosphate Adsorption Kinetics

The iron/nitrogen co-modified biochar reached the adsorption equilibrium within 24 h, with an equilibrium adsorption capacity of 18.75 mg/g (q_e = 18.75 mg/g). The adsorption was 4.7 and 3.7 times higher than that of unmodified biochar (3.98 mg/g) and attapulgite (5.07 mg/g), respectively (Table 2). The adsorption process was more in line with the pseudo-second-order kinetic model (R^2 = 0.99). Therefore, the dominant mechanism was chemisorption, which includes ligand exchange between Fe^{3+} and PO_4^{3-} and electrostatic attraction of nitrogen functional groups (Li & Shi, 2022). It is noteworthy that the apparent rate constant of the Fe-N material (k_2 = 0.24 g/(mg-min)) was lower than that of the attapulgite (0.61 g/(mg-min)), which may be related to the mass transfer resistance of the microporous structure, but its adsorption amount at equilibrium (18.75 mg/g) is still significantly higher than that of attapulgite (Figure 1).

Figure 1. *Kinetics of phosphorus adsorption by different materials*



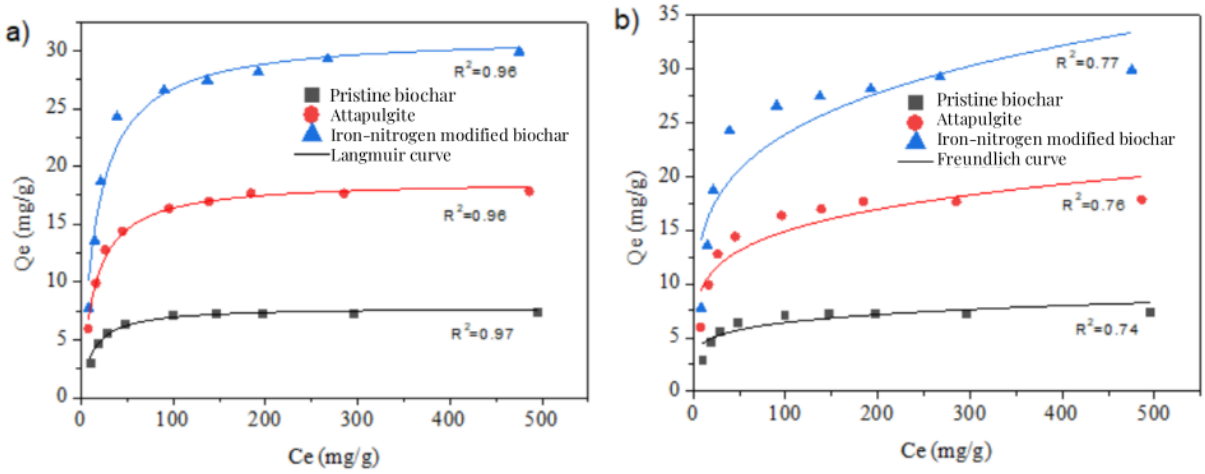
(a) Pseudo-first-order kinetic model fitting (b) Pseudo-second-order kinetic model fitting

Table 2. *Adsorption kinetics Parameters of Biochar and Its modified materials*

Materials	Proposed-first-order kinetics			Pseudo-second-order kinetics		
	q_e (mg/g)	k_1 (1/min)	R^2	q_e (mg/g)	k_2 (g/mg*min)	R^2
Pristine biochar	3.63	1.25	0.97	3.98	0.40	0.98
Attapulgite	4.74	2.26	0.96	5.07	0.61	0.96
Iron-nitrogen-modified biochar	17.74	3.09	0.96	18.75	0.24	0.99

3.3 Phosphate Adsorption Isotherms and Capacity

Figure 2. *Isotherms of phosphorus adsorption for different materials*



(a) Langmuir isotherm fitting for pristine biochar, attapulgite, and iron–nitrogen modified biochar

(b) Freundlich isotherm fitting for pristine biochar, attapulgite, and iron–nitrogen modified biochar

Langmuir model fitting showed (Table 3) that the maximum adsorption capacity of Fe/N-BC (q_m = 31.34 mg/g) was 3.98 times higher than that of unmodified biochar (7.87 mg/g). These results suggested that Fe–N co-modification greatly enhanced raw biochar's phosphorus adsorption capacity. Reported values for other materials, such as Mg/Al-modified biochar (6.10 mg/g) (Li S. et al., 2021) and Fe-BC690 (26.14 mg/g) (Li B. et al., 2021), suggest that Fe/N-BC had a comparatively high adsorption capacity. The Freundlich constant (K_F = = 8.94 L/mg) indicated a high density of heterogeneous adsorption sites on the surface of the material, and the $^1/_n$ value (0.21) showed moderate adsorption intensity, suggesting a moderate affinity for phosphate (Figure 2). While its isotherm performance is still below that of Mg-modified coffee grounds biochar (q_m = 63.5 mg/g) (Shin et al., 2020), Fe/N-BC offers greater advantages in terms of raw material costs and regeneration potential.

Table 3. *Isotherm parameters of phosphorus adsorption for different materials*

Materials	Langmuir adsorption model			Freundlich adsorption model		
	q_m(mg/g)	K_L(L/mg)	R^2	K_F(L/mg)	1/n	R^2
Pristine biochar	7.87	0.08	0.97	3.07	0.16	0.74
Iron-nitrogen-modified biochar	31.34	0.05	0.96	8.94	0.21	0.77
Attapulgite	18.75	0.05	0.96	6.34	0. 19	0.76

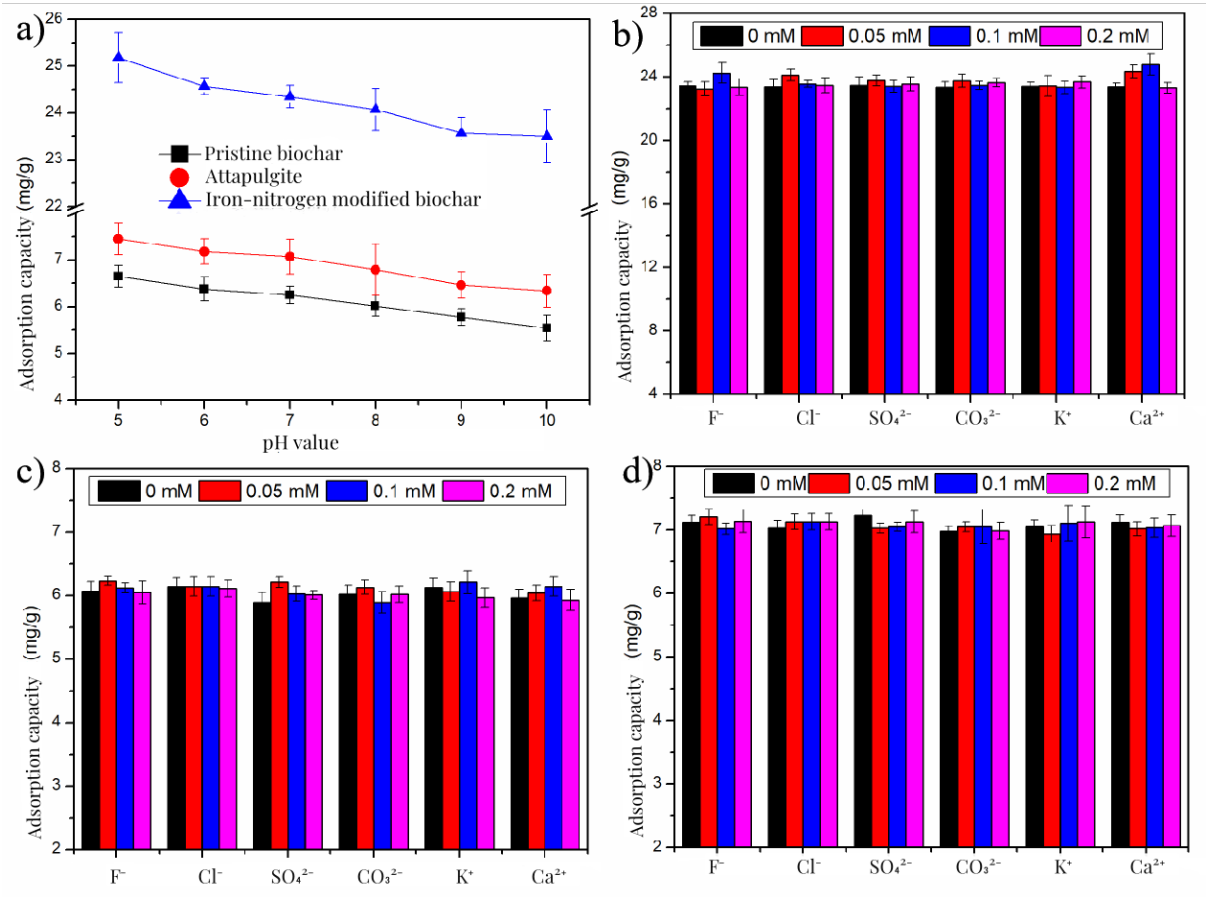
3.4 Influence of environmental factors

The varying pH of the solution affects the adsorption capacity and surface properties of biochar and chemical forms of phosphate in solution (Hou et al., 2020). In addition, phosphorus adsorption is affected by coexisting anions in the solution (Luo et al., 2023), which compete with the phosphate ions for adsorption sites. The presence of anions such as Cl^-, F^-, SO_4^{2-}, and HCO_3^- can inhibit phosphate uptake. As shown in Figure 4a, Fe/N-BC consistently showed the highest phosphate adsorption capacity across all pH values (5–10). When pH < 7, phosphate primarily exists as $H_2PO_4^-$, which was easily complexed with metal sites on the surface of the material (e.g., Fe^{3+}) (Ping et al., 2023), and thus Fe/N-BC had a higher adsorption capacity at lower pH. The best adsorption performance of Fe/N-BC (25.1 mg/g) was obtained at pH = 5, which was consistent with the optimal adsorption pH of γ-Al_2O_3/Fe_3O_4-modified biochar (Cui et al., 2020).

Moreover, the change in pH has different effects on phosphorus adsorption. According to Luo et al. 2023, at pH below the point of zero charge (pHpzc) of the biochar, surface functional groups become protonated and positively charged, thus enhancing the adsorption of anionic phosphate species through electrostatic attraction. As the solution pH increases, surface groups become deprotonated and negatively charged, leading to a reduced adsorption capacity (Luo et al., 2023).

Under the influence of coexisting ions and different ion strengths, the results showed that the adsorption capacity of pristine biochar, iron-nitrogen-modified biochar, and attapulgite on phosphorus all exhibited slight fluctuations (Figure 3). These slight changes indicate that the influence of environmental ions on phosphorus adsorption of the three materials is relatively small. The findings are consistent with the chemisorption mechanism supported by kinetic and spectroscopic analyses. In addition, it can be seen that under the ion type and ion strength conditions, the adsorption capacity of iron-nitrogen-modified biochar for phosphorus was consistently higher than that of pristine biochar and attapulgite, further demonstrating its enhanced adsorption capacity.

Figure 3. *Effect of pH, coexisting ion types, and ion concentrations on phosphate adsorption capacity*



(a) Influence of pH value on the adsorption capacity of pristine biochar, attapulgite, and iron-nitrogen-modified biochar.

(b) Influence of different coexisting ions and their concentrations on adsorption by iron-nitrogen-modified biochar.

(c) Influence of different coexisting ions and their concentrations on adsorption by pristine biochar.

(d) Influence of different coexisting ions and their concentrations on adsorption by attapulgite.

3.5 Adsorption Mechanism Analysis

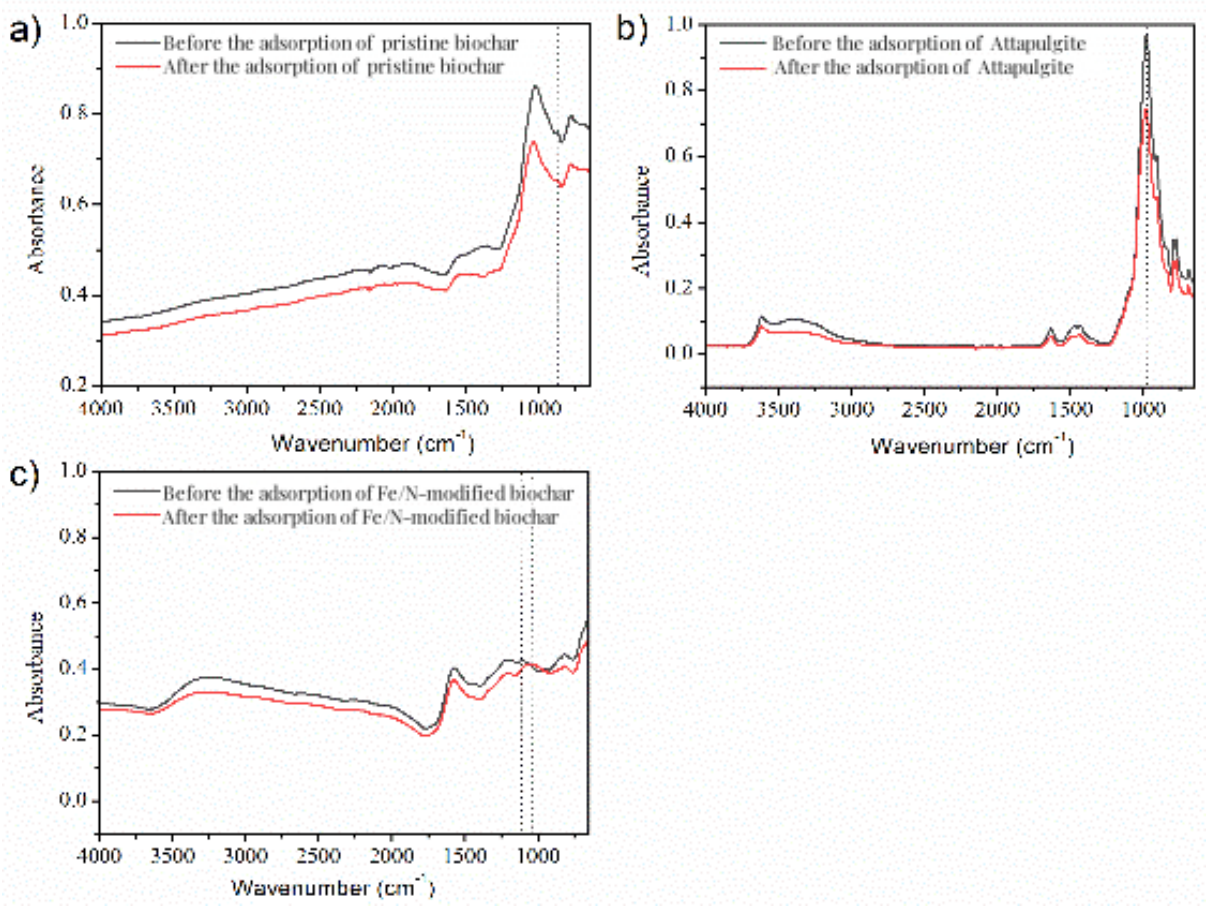
Generally, the adsorption mechanisms of the phosphate adsorption adsorbent are electrostatic interaction, ion exchange, surface complexation, and precipitation (Huang et al., 2024). In this study, Fe/N-BC's enhanced capacity is mainly due to its surface chemical structure and the synergistic effect of multiple adsorption mechanisms. Firstly, iron modification provided essential phosphate-binding sites. After phosphate was adsorbed onto Fe/N-BC, a distinct Fe–O–P vibration band appeared in the FTIR spectrum at approximately 1120 cm^{-1} (Figure 4). This feature indicates that phosphate ions formed stable complexes or precipitates with Fe^{3+}/FeOOH through ligand exchange or surface complexation. Secondly, nitrogen doping introduced electron-rich functional groups such as pyrrolic-N, amino (–NH_2), and amide groups. This modification greatly increased the surface electron density and hydrophilicity of the material. Also, the decreased intensity of the pyrrole-N peak at 1620 cm^{-1} (Figure 4) suggests that nitrogen functional groups are involved in adsorption through hydrogen bonding. Together, these properties made the material more favorable for interacting with phosphate ions.

In addition to the chemical transformations mentioned above, Fe and N also work together during material formation to shape the structure of the material. Firstly, $FeCl_3$

acted as the pore-forming component during pyrolysis. It promoted the formation of hierarchical micro-, meso-, and macro-pores. These pores facilitated the transport of phosphates and served as additional routes for phosphate dispersion (Yang et al., 2011). Also, the decomposition of urea released gases such as ammonia (NH_3) and carbon dioxide (CO_2) (Xiang et al., 2012). These gases expanded the carbon framework, especially contributing to the formation of mesopores that further increased the specific surface area and the amount of surface active sites. Together, both Fe and N provided the material with the advantages of both high porosity and a high content of surface functional groups.

Moreover, electrostatic attraction and surface precipitation also contribute to phosphate removal (Wu et al., 2020). Under low pH conditions, the material surface is positively charged, which favors the adsorption of negatively charged species such as $H_2PO_4^-$ and HPO_4^{2-}. In neutral to alkaline environments, Fe^{3+} can further react with PO_4^{3-} to form precipitates like $FePO_4$ to reduce phosphate concentrations in solution (Li et al., 2018).

Figure 4. *Comparison of FTIR spectra of the three materials before and after phosphorus adsorption*



(a) Pristine biochar before and after adsorption;

(b) Attapulgite before and after adsorption;

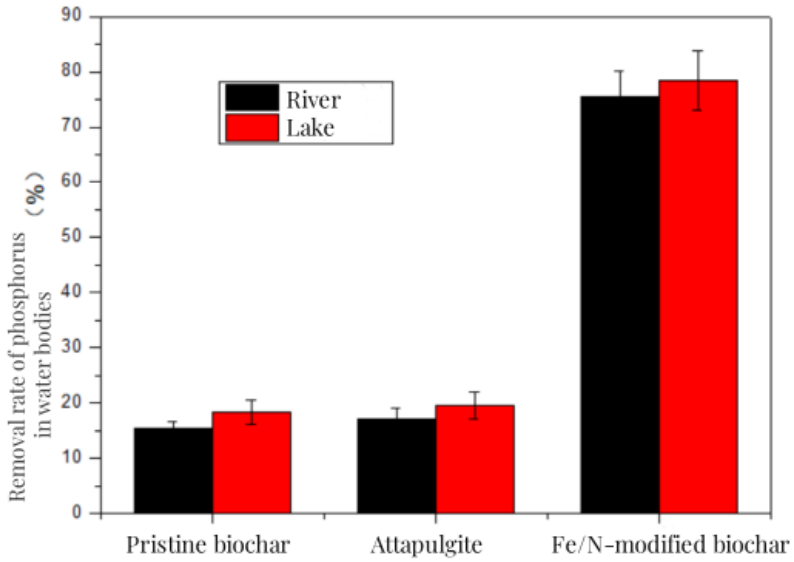
(c) Fe/N–modified biochar before and after adsorption.

3.6 Practical Application Potential

One important indicator of a phosphorus adsorbent's effectiveness in real-world applications is how well it removes phosphorus from actual water sources. In this study, Fe/N-BC maintained good phosphorus removal performance in real river and lake wa-

ter samples, with a removal rate of 75% and nearly 80% respectively (Figure 5). This result reflects its strong adsorption capacity and environmental adaptability. Its strong resistance to interference is likely due to the selective binding of the surface Fe–O active sites and nitrogen-containing functional groups toward phosphate ions. Therefore, compared to pristine biochar and attapulgite, Fe/N-BC had a more stable performance and was less affected by environmental conditions, which include coexisting organic matter, anions, and slight pH fluctuations. Moreover, because of its advantages, such as strong environmental compatibility and cost-effectiveness, Fe/N-BC shows great promise for application in real-world scenarios. Potential applications include agricultural runoff treatment, eutrophication control in lakes, and phosphorus recovery from wastewater for sustainable reuse.

Figure 5. *Comparison of the phosphorus adsorption effects of three adsorption materials on actual water bodies*



4. Conclusion

This study introduced an iron/nitrogen co-modified biochar (Fe/N-BC), produced by pretreating rice straw with $FeCl_3$ and urea and followed by one-step pyrolysis, and evaluated its potential for phosphorus removal. Results showed that Fe/N-BC had a highly porous structure with a specific surface area of 916.5 m^2/g, exceeding that of raw biochar and attapulgite. Regarding adsorption kinetics and capacity, the adsorption process followed the pseudo-second-order kinetics model and indicated chemisorption as the dominant mechanism; Fe/N-BC achieved a maximum phosphate adsorption capacity of 31.34 mg/g, the highest among all tested materials. FTIR analysis showed that both Fe–O–P complexation and nitrogen-containing functional groups toward phosphate ions contributed to effective phosphate removal. Under the influence of varying pH, coexisting ions, and different ion strengths, Fe/N-BC still maintained the highest adsorption capacity among the tested materials. Most importantly, in real river and lake samples, Fe/N-BC had a stable phosphorus removal performance with nearly a 75% and nearly an 80% removal rate, respectively, and showed its potential for mitigating eutrophication. By analyzing its structural characteristics, adsorption kinetics and capacity, influencing factors, and application in real-world water samples, this study proved the Fe–N co-modification technique to be a promising material for enhancing raw biochar's phosphorus removal ability. Thus, this Fe/N co-modification method introduces a practical approach to developing more effective phosphate adsorbents.

5. Limitations and Future Perspectives

In this study, although the Fe/N co-modification method greatly enhanced the adsorption capacity compared to pristine biochar and attapulgite, there is still room for improvement. Other types of biochar, made from various raw materials, varying pyrolysis conditions, and different modification techniques, may achieve higher adsorption capacities than that of Fe/N-BC. Therefore, future research should focus on improving the Fe/N co-modification process, such as adjusting the pyrolysis temperature and the $FeCl_3$-to-urea ratio, to improve adsorption kinetics and capacity and reduce micropore-related mass transfer limits. Also, researchers should gain a more thorough understanding of how iron and nitrogen work together at the molecular level. This understanding can help with the design of more selective and efficient phosphate adsorbents.

Additionally, this study did not investigate the regeneration potential of Fe/N-BC after phosphate saturation. Therefore, in practical applications, more research is needed to study the reusability and applications of the phosphate-saturated adsorbent, such as in the form of slow-release fertilizer. Moreover, testing Fe/N-BC in different types of real water bodies, like polluted rivers or reservoirs, will help confirm whether the material performs well under more complex, real-world conditions. These future efforts are vital in addressing eutrophication, supporting sustainable resource recovery, and promoting the large-scale applications of biochar.

References

Cheng, N., Wang, B., Wu, P., Lee, X., Xing, Y., Chen, M., & Gao, B. (2021). Adsorption of emerging contaminants from water and wastewater by modified biochar: A review. *Environmental Pollution, 273,* 116448. URL: https://doi.org/10.1016/j.envpol.2021.116448

Cui, Q., Xu, J., Wang, W., Tan, L., Cui, Y., Wang, T., Li, G., She, D., & Zheng, J. (2020). Phosphorus recovery by core-shell γ-Al_2O_3/Fe_3O_4 biochar composite from aqueous phosphate solutions. *Science of The Total Environment, 729,* 138892. URL: https://doi.org/10.1016/j.scitotenv.2020.138892

Hou, L., Liang, Q., & Wang, F. (2020). Mechanisms that control the adsorption–desorption behavior of phosphate on magnetite nanoparticles: The role of particle size and surface chemistry characteristics. *RSC Advances,* – 10(4). – P. 2378–2388. URL: https://doi.org/10.1039/C9RA08517C

Huang, R., Lu, X., Li, W., Xiong, J., & Yang, J. (2024). Progress on the adsorption characteristics of nZVI and other iron-modified biochar for phosphate adsorption in water bodies. *Circular Economy,* – 3(4). – 100112 p. URL: https://doi.org/10.1016/j.cec.2024.100112

Li, B., Jing, F., Hu, Z., Liu, Y., Xiao, B., & Guo, D. (2021). Simultaneous recovery of nitrogen and phosphorus from biogas slurry by Fe-modified biochar. *Journal of Saudi Chemical Society,* – 25(4). – 101213 p. URL: https://doi.org/10.1016/j.jscs.2021.101213

Li, S., Ma, X., Ma, Z., Dong, X., Wei, Z., Liu, X., & Zhu, L. (2021). Mg/Al-layered double hydroxide modified biochar for simultaneous removal phosphate and nitrate from aqueous solution. *Environmental Technology & Innovation,* – 23. – P. 101771. URL: https://doi.org/10.1016/j.eti.2021.101771

Li, X., & Shi, J. (2022). Simultaneous adsorption of tetracycline, ammonium and phosphate from wastewater by iron and nitrogen modified biochar: Kinetics, isotherm, thermodynamic and mechanism. *Chemosphere,* – 293. – 133574 p. URL: https://doi.org/10.1016/j.chemosphere.2022.133574

Li, Y., He, X., Hu, H., Zhang, T., Qu, J., & Zhang, Q. (2018). Enhanced phosphate removal from wastewater by using in situ generated fresh trivalent Fe composition through the interaction of Fe(II) on CaCO3. *Journal of Environmental Management*, – 221. – P. 38–44. URL: https://doi.org/10.1016/j.jenvman.2018.05.018

Li, Y., Xu, R., Wang, H., Xu, W., Tian, L., Huang, J., Liang, C., & Zhang, Y. (2022). Recent advances of biochar-based electrochemical sensors and biosensors. *Biosensors,* – 12(6). – 377 p. URL: https://doi.org/10.3390/bios12060377

Li, Z., Liu, X., & Wang, Y. (2020). Modification of sludge-based biochar and its application to phosphorus adsorption from aqueous solution. *Journal of Material Cycles and Waste Management,* – 22(1). – P. 123–132. URL: https://doi.org/10.1007/s10163-019-00921-6

Lin, F., Wang, L., Dai, X., Man, Z., Meng, Y., Chu, D., Yang, Y., Wang, W., Xiao, H., & Wang, K. (2024). Catalytic fixation of hydrogen sulfide over CuO–$CaCO_3$ co-impregnated tea stalk-derived biochar. *Journal of Environmental Chemical Engineering,* – 12(5). – 113320 p. URL: https://doi.org/10.1016/j.jece.2024.113320

Liu, S., Zhao, C., Wang, Z., Ding, H., Deng, H., Yang, G., Li, J., & Zheng, H. (2020). Urea-assisted one-step fabrication of a novel nitrogen-doped carbon fiber aerogel from cotton as metal-free catalyst in peroxymonosulfate activation for efficient degradation of carbamazepine. *Chemical Engineering Journal,* – 386. – 124015 p. URL: https://doi.org/10.1016/j.cej.2020.124015

Luo, D., Wang, L., Nan, H., Cao, Y., Wang, H., Kumar, T. V., & Wang, C. (2023). Phosphorus adsorption by functionalized biochar: A review. *Environmental Chemistry Letters,* – 21(1). – P. 497–524. URL: https://doi.org/10.1007/s10311-022-01519-5

Mei, Y., Xu, J., Zhang, Y., Li, B., Fan, S., & Xu, H. (2021). Effect of Fe-N modification on the properties of biochars and their adsorption behavior on tetracycline removal from aqueous solution. *Bioresource Technology,* – 325. – 124732 p. URL: https://doi.org/10.1016/j.biortech.2021.124732

Pan, F., Wei, H., Huang, Y., Song, J., Gao, M., Zhang, Z., Teng, R., & Jing, S. (2024). Phosphorus adsorption by calcium chloride-modified buckwheat hulls biochar and the potential application as a fertilizer. *Journal of Cleaner Production,* – 444. – 141233 p. URL: https://doi.org/10.1016/j.jclepro.2024.141233

Ping, Q., Zhang, B., Zhang, Z., Lu, K., & Li, Y. (2023). Speciation analysis and formation mechanism of iron-phosphorus compounds during chemical phosphorus removal process. *Chemosphere,* – 310. – 136852 p. URL: https://doi.org/10.1016/j.chemosphere.2022.136852

Qian, L., Zhonghua, Y., Wei, Y., Minghui, Y., Fengpeng, B., Yao, Y., & Yufeng, R. (2023). Tracing the sources and transport of the total phosphorus in the upper Yangtze River. *Ecological Informatics,* – 77. – 102230 p. URL: https://doi.org/10.1016/j.ecoinf.2023.102230

Shin, H., Tiwari, D., & Kim, D.-J. (2020). Phosphate adsorption/desorption kinetics and P bioavailability of Mg-biochar from ground coffee waste. *Journal of Water Process Engineering,* – 37. – 101484 p. URL: https://doi.org/10.1016/j.jwpe.2020.101484

Singh, J., Bhattu, M., Liew, R. K., Verma, M., Brar, S. K., Bechelany, M., & Jadeja, R. (2025). Transforming rice straw waste into biochar for advanced water treatment and soil amendment applications. *Environmental Technology & Innovation,* – 37. – 103932 p. URL: https://doi.org/10.1016/j.eti.2024.103932

United Nations Environment Programme. (2024, January 24). What is phosphorus and why are concerns mounting about its environmental impact? *UNEP*. URL: https://www.unep.org/news-and-stories/story/what-phosphorus-and-why-are-concerns-mounting-about-its-environmental-impact

Wu, B., Wan, J., Zhang, Y., Pan, B., & Lo, I. M. C. (2020). Selective Phosphate Removal from Water and Wastewater using Sorption: Process Fundamentals and Removal Mechanisms. *Environmental Science & Technology*, – 54(1). – P. 50–66. URL: https://doi.org/10.1021/acs.est.9b05569

Xiang, X., Guo, L., Wu, X., Ma, X., & Xia, Y. (2012). Urea formation from carbon dioxide and ammonia at atmospheric pressure. *Environmental Chemistry Letters*, – 10(3). – P. 295–300. URL: https://doi.org/10.1007/s10311-012-0366-2

Yang, J., Zhou, L., Zhao, L., Zhang, H., Yin, J., Wei, G., & Yu, C. (2011). A designed nanoporous material for phosphate removal with high efficiency. *Journal of Materials Chemistry,* – 21(8). – P. 2489–2494. URL: https://doi.org/10.1039/C0JM02718A

Yi, Y., Wang, X., Ma, J., & Ning, P. (2021). Fe(III) modified *Egeria najas*-driven biochar for highly improved reduction and adsorption performance of Cr(VI). *Powder Technology,* – 388. – P. 485–495. URL: https://doi.org/10.1016/j.powtec.2021.04.066

Zhou, X., Liu, Y., Zhou, J., Guo, J., Ren, J., & Zhou, F. (2018). Efficient removal of lead from aqueous solution by urea-functionalized magnetic biochar: Preparation, characterization and mechanism study. *Journal of the Taiwan Institute of Chemical Engineers,* – 91. – P. 457–467. URL: https://doi.org/10.1016/j.jtice.2018.04.018

Zubrowska-Sudol, M., & Walczak, J. (2015). Enhancing combined biological nitrogen and phosphorus removal from wastewater by applying mechanically disintegrated excess sludge. *Water Research,* – 76. – P. 10–18. URL: https://doi.org/10.1016/j.watres.2015.02.041

submitted 10.08.2025;
accepted for publication 24.08.2025;
published 30.09.2025

Contact: ymgao07@gmail.com

European Science Review 2025,
No 7–8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 2. Economics and Management

DOI:10.29013/ESR-25-7.8-15-20

THE ECONOMIC IMPACT OF EXPORT MARKETS ON SMALL AND MEDIUM-SIZED ENTERPRISES (SMEs)

Abdukahhorov Azizbek Abdullo o'gli [1]

[1] Independent researcher at Tashkent State University of Economics

Cite: *Abdukahhorov, A.A. (2025). The economic impact of export markets on small and medium-sized enterprises (SMEs). European Science Review 2025, No 7–8.* https://doi.org/10.29013/ESR-25-7.8-15-20

Abstract

This study explores the economic implications of engaging in export markets for small and medium-sized enterprises (SMEs). Drawing on empirical data from various countries, including Vietnam, Turkey, Uzbekistan, South Korea, and Poland, the research examines how export participation affects SME growth, productivity, employment, and survival. It also highlights key obstacles faced by SMEs in international markets. The findings support the assertion that exporting significantly enhances SME performance, yet access barriers and capability constraints remain. Policy recommendations are offered to support SME internationalization through targeted reforms, trade facilitation, and financial instruments.

Keywords: *Export markets, SMEs, productivity, trade barriers, firm growth, competitiveness*

Introduction

Small and medium-sized enterprises (SMEs) account for the majority of businesses and employment globally. According to the International Trade Centre (2022), SMEs represent more than 95% of registered firms and employ over 60% of the global workforce. In developing countries, their contribution to GDP ranges from 25% to 40%. Despite their critical economic role, SMEs often operate in local markets with limited exposure to global value chains.

The globalized trade environment provides a unique opportunity for SMEs to grow through access to foreign demand. Exporting allows SMEs to scale operations, enhance learning and innovation, diversify revenue, and reduce dependency on domestic markets. However, many SMEs struggle to engage in exporting due to financial constraints, complex regulations, and lack of information.

This research analyzes the tangible benefits and persistent challenges of SME export participation. It focuses on countries with varied trade and development profiles to identify generalizable and region-specific patterns in export impact.

Literature Review

The literature on SMEs and exports reveals a strong consensus that export participation is

positively correlated with firm performance. Several frameworks and models have been used to explain this relationship:

Melitz (2003) argues that only the most productive firms enter export markets, a phenomenon known as "self-selection (Melitz, M.J., 2003)" Bernard and Jensen (1999) support this by showing that exporters outperform non-exporters in terms of productivity, wages, and size even before they start exporting (Bernard, A.B., & Jensen, J.B., 1999). However, studies such as De Loecker (2007) suggest that firms also learn from exporting by gaining access to new knowledge and technologies (De Loecker, J., 2007).

Wagner (2012) reviewed over 50 firm-level studies and concluded that exporters show superior performance across various indicators (Wagner, J., 2012). This is echoed by Van Biesebroeck (2005), who found that African exporters experienced higher productivity due to scale economies and global competition exposure (Van Biesebroeck, J., 2005).

Despite the benefits, OECD (2018) points out that SMEs face considerable entry costs when exporting. These include high compliance costs, certification procedures, and lack of logistics capabilities (OECD., 2018). The World Bank (2021) emphasizes the need for targeted support mechanisms, especially for SMEs in developing regions (World Bank, 2021).

In Vietnam, Nguyen et al. (2020) documented substantial productivity gains among exporting SMEs, especially in the manufacturing sector (Nguyen, T. A., et al., 2020).

Polish SMEs experienced export-driven employment growth but faced difficulties adapting to EU regulatory standards (Kowalski, P., 2017).

Uzbek SMEs have recently expanded export activity due to state reforms, but challenges in trade finance and infrastructure persist (ADB., 2023).

Methodology

This study utilizes a comparative case study and descriptive statistical analysis approach based on secondary data. The methodology follows these key steps:

Sources: World Bank Enterprise Surveys (2022), OECD SME Outlook (2022), ITC SME Competitiveness Reports, national statistics offices.

Period: 2010–2022.

Selected Countries: Vietnam, Turkey, Uzbekistan, South Korea, and Poland.

The following firm-level economic indicators were compared for exporting and non-exporting SMEs:

Revenue Growth (% annual average)

Productivity Gains (% value added per worker)

Employment Growth (% change in staff count)

Export Market Duration (survival rate of exporting SMEs after 3+ years)

Results and Analysis

Across all surveyed countries, SMEs that export demonstrated higher revenue growth rates compared to non-exporters. For instance:

Vietnamese exporting SMEs recorded 13.5% average annual growth over five years, significantly outperforming non-exporting counterparts at 6.1%. This growth has been attributed to favorable trade policies, access to ASEAN markets, and active government export promotion programs.

South Korean SMEs showed a similar trend, averaging 15.4% annual growth. Government-led initiatives such as the "K-Sure Export Insurance" and subsidized participation in international fairs contributed to this rise.

Uzbekistan's exporting SMEs, though at a lower base, achieved 9.1% growth, compared to 4.2% for domestic-only firms. This improvement correlates with recent liberalization policies, improved customs procedures, and trade agreements with CIS countries and China.

These findings suggest that exporting creates a multiplier effect – international demand stimulates production, leads to higher unit sales, and allows businesses to reinvest profits into capacity expansion.

Export exposure typically requires firms to meet international standards, comply with stricter quality controls, and integrate better technologies. These requirements lead to increased workforce efficiency, optimized processes, and improved capital utilization.

Table 1. *Exporting SMEs Growth (UNCTAD, 2021)*

Country	Exporting SMEs Growth (%)	Productivity Gain (%)	Top Barriers
Vietnam	13.5%	30%	Customs delays, finance
Turkey	10.2%	22%	Currency fluctuation
Uzbekistan	9.1%	25%	Infrastructure, awareness
South Korea	15.4%	35%	Regulatory burden
Poland	12.3%	28%	EU compliance standards

Table 2. *Resilience and Business Survival: Exporting as a Risk Management Tool*

Country	Survival Rate of Exporting SMEs (5 Years)	Non-Exporting SMEs
South Korea	72%	52%
Poland	70%	54%
Vietnam	66%	50%
Uzbekistan	65%	48%

A key insight is that productivity gains from exporting are not instantaneous. In most countries, the biggest improvements were reported 2–3 years after initial export activity, pointing to a learning-by-exporting dynamic.

Exporting SMEs also contribute more significantly to job creation than their non-exporting peers:

On average, exporting SMEs expanded employment by 18% over a five-year period, compared to 7% for non-exporters.

Sectors such as textile, electronics, food processing, and ICT saw the most significant employment growth due to strong foreign demand and global supply chain integration.

In Uzbekistan, the government's "Export-Oriented Industrialization" program led to the establishment of hundreds of export-linked jobs in free economic zones such as Navoi and Angren. Similarly, in Poland, SMEs in the furniture and automotive parts sector hired more workers after gaining access to Western European markets.

Moreover, exporting tends to increase employment quality, as firms are more likely to offer contracts, benefits, and skill training to meet global compliance standards.

Another key metric analyzed is the survival rate of exporting SMEs. Results indicate that firms engaging in exports are more likely to withstand economic shocks and persist in the long run:

South Korea and Poland showed the highest export SME survival rates, exceeding 70% over a five-year period.

In Vietnam and Uzbekistan, survival rates hovered around 65%, indicating moderate resilience improvements from export engagement.

Non-exporting SMEs, on the other hand, showed survival rates closer to 48–55%, suggesting greater vulnerability to market fluctuations and competition.

This outcome may stem from revenue diversification. Firms relying solely on domestic sales are more exposed to regional downturns, political instability, or consumer demand shifts. Exporting provides an insurance-like effect through market diversification.

Analyzing the performance trend reveals that:

Exporting SMEs have shown stronger recovery post-COVID-19, especially in digitalized and technology-adaptive sectors.

The growth gap between exporters and non-exporters widened after major trade agreements or policy reforms (e.g., Uzbekistan's customs reform in 2019 or Vietnam's EVFTA implementation in 2020; Enterprise Surveys, 2022).

Firms that combined product innovation and foreign expansion exhibited the most sustainable gains.

The analysis of constraints highlights non-price barriers as the dominant issue for SMEs. These include:

Information asymmetries: Lack of buyer databases, unclear compliance requirements, and no centralized trade facilitation portals disproportionately hurt SMEs.

Export finance: 58% of surveyed SMEs report lack of access to affordable export loans, insurance, or guarantees – especially acute in Uzbekistan and Turkey.

Logistics and customs: Weak border infrastructure, inconsistent tariff classification, and bribes at checkpoints reduce SME competitiveness.

A cost-benefit framework shows that initial fixed costs of export entry (certification, packaging, registration) can be equivalent to 10–15% of annual revenue for micro-SMEs. Without subsidies or pooled services (e.g., trade facilitation centers), this creates a structural exclusion.

Discussion

The evidence reaffirms the role of exports in enhancing SME performance. By tapping into global demand, firms are incentivized to modernize, increase efficiency, and adopt higher standards. These effects are more pronounced in manufacturing and ICT sectors due to scale potential and international competition.

Despite positive outcomes, the entry cost remains disproportionately high for SMEs, especially in countries with limited infrastructure or regulatory bottlenecks. Exporting SMEs in developing economies face additional burdens such as volatile exchange rates, limited export insurance, and weak logistics networks.

Countries with robust export promotion agencies, such as Vietnam and South Korea, outperform others in SME export sustainability. This supports the argument by Alvarez and Lopez (2005) that public policy plays a pivotal role in SME internationalization (Alvarez, R., & Lopez, R.A., 2005).

Table 3. *Comparative Country Performance Analysis*

Country	Exporting SME Growth	Productivity Gain	Job Growth	Resilience Index	Institutional Support Index
South Korea	High	Very High	High	Very Strong	Excellent (KOTRA, K-SURE)
Vietnam	High	High	High	Strong	Good (Trade Hub Model)
Uzbekistan	Moderate	Moderate–High	Moderate	Moderate	Improving (Customs Reform)
Turkey	Moderate	Low–Moderate	Moderate	Moderate	Partial (Inflation Exposure)
Poland	High	High	High	Strong	Strong (EU Integration)

Source: Polish Agency for Enterprise Development (PARP), (2022); OECD-Turkey Joint Report (2021)

The resilience index reflects diversification, policy response, and export market continuity during crises.

The institutional support index captures the strength of national trade support programs (e.g., KOTRA in Korea, Trade Promotion Council in Vietnam, and Eximbank in Poland).

South Korea, Vietnam, and Poland demonstrate “high” SME growth due to mature ex-

port ecosystems, early-stage support programs, and access to diversified markets.

Uzbekistan and Turkey, although progressing, face institutional bottlenecks and export concentration, leading to only "moderate" SME export growth.

For example, Turkey's SME exports are overly reliant on a few sectors (textiles, machinery), making growth sensitive to global demand shifts.

Uzbekistan's recent reforms have unlocked new growth, but results are still stabilizing.

South Korea leads with "very high" productivity gain, attributed to intensive R&D policies, government co-financing of innovation, and mandatory exporter training. Poland and Vietnam also show strong productivity improvements, often linked to EU regulations and FTAs, which compel SMEs to adopt efficient production and quality control systems. Uzbekistan, with "moderate–high" gains, has benefited from imported capital goods and knowledge spillovers, especially in Free Economic Zones (FEZs), though technological adoption remains uneven. Turkey, constrained by macroeconomic volatility and weak linkages with R&D institutions, shows only marginal gains.

Employment effects mirror the growth trends, with Vietnam, South Korea, and Poland creating more jobs due to:

Expansion in labor-intensive sectors,

Incentives for hiring under export promotion laws,

Integrated vocational education tied to export clusters.

Uzbekistan and Turkey face labor market rigidities and skill mismatches. In Turkey, firms face high social security costs, while in Uzbekistan, skilled labor shortages in rural areas limit export scaling.

South Korea and Poland represent export policy maturity, where institutional architecture is deeply embedded in national development strategy. Vietnam demonstrates the effectiveness of coordinated decentralization, where sectoral export promotion works at provincial levels. Uzbekistan is at a turning point – strong government commitment and early reforms are promising, but success depends on full implementation and SME capacity building. Turkey must address macroeconomic volatility and institutional fragmentation to unlock higher SME export performance.

Many exporting SMEs benefited from increasing returns to scale, as foreign market access allowed firms to increase production without proportionate increases in costs. For instance, Polish SMEs in industrial machinery leveraged long-term contracts in Germany to double output with only a 40% increase in labor costs.

This supports endogenous growth theory's assertion that export market access acts as a technology accelerator and encourages human capital investment, both of which are key for long-term development.

Conclusion

This research demonstrates that engaging in export markets significantly improves the economic performance of SMEs. Exporting fosters revenue growth, productivity, employment, and survival, contributing to broader economic development. However, to fully realize this potential, targeted policies must address financial, institutional, and knowledge-based barriers. A holistic export support ecosystem is essential to unlock the transformative power of trade for SMEs, especially in developing countries.

References

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica, – 71(6). – P. 1695–1725.

Bernard, A.B., & Jensen, J.B. (1999). Exceptional exporter performance: Cause, effect, or both? Journal of International Economics, – 47(1). – P. 1–25.

De Loecker, J. (2007). Do exports generate higher productivity? Journal of International Economics, – 73(1). – P. 69–98.

Wagner, J. (2012). International trade and firm performance: A survey of empirical studies since 2006. Review of World Economics, – 148(2). – P. 235–267.

Van Biesebroeck, J. (2005). Exporting raises productivity in sub-Saharan African manufacturing firms. Journal of International Economics, – 67(2). – P. 373–391.

OECD., (2018). SME and Entrepreneurship Outlook. Paris: OECD Publishing.
World Bank, (2021). Doing Business Report: Trading Across Borders. Washington, DC.
ITC. (2022). SME Competitiveness Outlook. Geneva: International Trade Centre.
Nguyen, T. A., et al. (2020). Exporting, productivity, and firm dynamics in Vietnam. Asian Economic Journal, –34(1). – P. 45–67.
Kowalski, P. (2017). SME internationalization in Central Europe. CEBRI Journal of Trade, – 24(4). – P. 102–117.
ADB. (2023). Uzbekistan SME Finance and Export Support Report. Manila: Asian Development Bank.
Alvarez, R., & Lopez, R. A., (2005). Exporting and performance: Evidence from Chilean plants. Canadian Journal of Economics, – 38(4). – P. 1384–1400.
UNCTAD. (2021). World Investment Report. United Nations.
Enterprise Surveys, (2022). World Bank Enterprise Surveys Data Portal.
Polish Agency for Enterprise Development (PARP) (2022). SME Sector in Poland: Structure, Performance, and EU Integration. Warsaw.
OECD-Turkey Joint Report (2021). Boosting Export Competitiveness and Innovation in Turkish SMEs.
Analyzes Turkey's SME ecosystem, barriers to export, and macroeconomic vulnerabilities.

submitted 05.07.2025;
accepted for publication 19.07.2025;
published 30.09.2025

Contact: mehrivoxidova@gmail.com

European Science Review 2025,
No 7–8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

DOI:10.29013/ESR-25-7.8-21-24

THE ROLE OF ARTIFICIAL INTELLIGENCE IN DEVELOPING COMPETITIVE HUMAN RESOURCES FOR BELARUS' FUTURE

Viktar Karpovich [1]

[1] Belarusian National University of Technology, Minsk

Cite: *Karpovich V. (2025). The role of artificial intelligence in developing competitive human resources for Belarus' future industry. European Science Review 2025, No 7–8*. https://doi.org/10.29013/ESR-25-7.8-21-24

Abstract

This study is dedicated to exploring the impact of artificial intelligence technologies on training highly qualified specialists in Belarusian universities. Trends in employment, structure of graduates, and readiness of educational systems for industrial transformation are analyzed. A survey among teachers highlighted the need for deep integration of AI methods into education, creation of adaptive learning trajectories, and enhancement of digital skills. Obstacles were identified and measures proposed to increase the effectiveness of digitization in the educational sphere.

Keywords: *Artificial Intelligence, Higher Education, Human Resource Development, Competitiveness, Digital Economy, Professional Competence, Educational Strategies, Belarus.*

Introduction

The current stage of human development is characterized by a transition to a new type of economy where the digital revolution brings fundamental changes to professional preparation systems. The conceptual core lies in the fact that Artificial Intelligence (AI) technologies determine the future of many industries, shaping specific competencies required for tomorrow's professionals. This poses an urgent task for higher education institutions – developing educational strategies enabling students to acquire relevant competencies and prepare for the conditions of the Fourth Industrial Revolution.

Materials and Methods

Methodology is based on foundational research in pedagogy and psychology, adult learning theory, and analysis of publications related to AI. Empirical methods such as observation, surveys, and expert interviews were employed. University curricula, employment statistics, and graduate numbers were also analyzed.

Results and Discussion

Research indicates that the Belarusian economy has undergone profound restructuring due to technological progress, globalization, and changing professional standards. From 2019 to 2024, there was a sharp rise in labor demand coupled with reduced supply.

On average, job vacancies reached 99,300 while official unemployment fell to 7,700, resulting in approximately 13 jobs per applicant (Karpovich, 2024). Industry distribution shows acute shortages in trade, industry, and certain working professions but excess staff in marketing, administrative, and IT sectors.

Analysis of higher education in Belarus revealed that during the academic year 2023–2024, personnel training took place at 49 universities enrolling 214,581 students. By 2024–2025, this network shrank to 47 institutions, reducing student enrollment to 207,198 bachelors and 10,400 master's candidates, along with a decrease in faculty from 17,600 to 17,200. Over the period 2019–2023, the number of graduates decreased by 19%, from 57,500 to 46,400. However, the greatest growth in graduates occurred in "Humanities" (+1.2 times) and "Security" (+1.15 times), whereas reductions were seen in fields like "Pedagogy" (–33.3%), "Agriculture and Forestry" (–26.4%), "Construction," "Economics and Management," and "Social Protection" (approximately 25–26% decline). Leading areas of specialization in 2023 included "Law, Economics, Communication, Management" (29.8%), "Technical Sciences and Engineering" (22.5%), and "Education and Pedagogy" (10.3%) (Karpovich, 2024).

Surveys conducted among university lecturers demonstrated strong interest in digital technologies in education: 23.5% considered information technology crucial for teaching quality, 52.9% supported using AI as a significant resource for enhancing educational efficiency, and only 5.9% expressed caution regarding risk assessment (Azanza, 2024).

Three main directions for effective use of AI technologies in education emerged from comprehensive analyses:

- deep integration of big data analytics techniques and automated systems for objective evaluation of student competence achievement levels (supported by 40.9% of surveyed experts);
- design and practical implementation of personalized distance-learning models tailored to individual cognitive activity patterns and preferences in receiving course materials (endorsed by 27.3% of respondents);
- widespread utilization of virtual assistants and chatbots as auxiliary pedagogical resources ensuring dynamic feedback between instructors and learners, thus improving acquisition of professional competencies (approved by 18.2% of participants) (Lin, 2024).

Approximately half of university professors support updating curriculum through introducing courses on artificial intelligence, neural networks, and machine learning. Additionally, they emphasize the importance of preparing specialists capable of interacting effectively with humans and AI alike. More than two-thirds of experts (62.5%) believe it necessary to include modules addressing ethical and legal issues concerning AI application, given its growing significance in social responsibility.

Despite widespread approval, some academics (6.25%) oppose premature expansion of these components within existing educational frameworks, citing insufficient methodology development and uncertainty about their practical usefulness in the domestic educational landscape.

Key obstacles to optimizing AI integration in higher education were noted by survey respondents:

- high cost of acquiring high-quality software and equipment (86.7%);
- insufficient material and technical infrastructure (53.3%);
- organizational challenges associated with implementing big data analytics (33.3%);
- low level of ICT expertise among employees (26.7%);
- personal data protection concerns (13.3%);
- passivity of university leadership in fostering digital environments (13.3%).

Thus, successful integration of AI technologies into higher education is constrained by structural, financial, personnel, and organizational limitations (Han, 2025). Addressing these challenges requires a comprehensive strategy encompassing increased funding for universities, enhanced technical infrastructure, regulatory framework development, and specialized training programs in Information Technology.

Systematic analysis of opinions from academia provides grounds to assert that perspectives on modernizing current educational standards vary widely;

- the most representative group (just over 41.2%) holds conservative views, arguing that the present system meets contemporary occupational demands without requiring substantial reform or detailed revision;
- another smaller yet influential segment (nearly 29.4%) advocates minor adjustments via modification of selected modules and sections of the curriculum.
- the third category, constituting a minority compared to the first two groups (~23.6%), insists on radical transformations across all aspects of educational content and structures, aiming to produce professionals ready to thrive in globalized informational spaces and rapidly evolving digital economies.

Students who have taken courses incorporating elements of AI demonstrate significantly higher motivation and engagement. Virtual assistants, automated simulators, and advanced diagnostic algorithms allow combining traditional teaching methods with innovative tools, thereby narrowing gaps between knowledge and industry requirements (Huang, 2023).

Nevertheless, Belarussian higher education faces serious difficulties stemming from deficiencies in professionally trained faculty members and limited infrastructure supporting broad adoption of AI technologies. Prioritizing gradual modernization of the entire educational sector, including deliberate inclusion of innovations in specialist training programs targeting promising economic sectors, becomes essential. Government policy should focus on establishing specialized research centers and laboratories aimed at designing and testing AI applications. Collaboration with foreign and local high-tech companies could be activated to co-design courses leveraging cutting-edge AI developments. Implementing such a strategy would overcome institutional barriers and lay foundations for producing highly skilled personnel equipped to address major contemporary challenges.

Conclusion

Modern challenges necessitate a thorough transformation of the national system for training specialists. Acquisition of new artificial intelligence technologies will become critical for maintaining competitive positions in global economic competition. Our findings underscore the urgency of immediate steps toward modernizing educational programs and integrating AI technologies, which promise to usher in a new era of educational achievements and enhance international recognition of Belarusian diplomas.

References

Karpovich, V. F. (2024). Institutional aspects of labor market conjunctural changes in Belarus. Symbol of Science: International Scientific Journal, 1(11-2), 52–55.

Karpovich, V. F. (2024). Analysis of the development of higher education system in the Republic of Belarus. In Aktual'nye voprosy sovremennoj nauki i obrazovaniya [Topical Issues of Modern Science and Education]: Proceedings of the XL International Scientific-Practical Conference (Vol. 2, pp. 169–171). Penza: Nauka i Prosveshchenie.

Azanza, G., Korres, O., Paños-Castro, J., & Petchamé, J. (2024). Empowering University Lecturers in the Digital Age: Exploring the Factors Influencing the Use of Digital Technologies in Higher Education. Education Sciences, 14(7), 728.

Lin, L., Zhou, D., Wang, J., & Wang, Y. (2024). A systematic review of big data driven education evaluation. Sage Open, 14(2), 21582440241242180.

Han, X., Xiao, S., Sheng, J., & Zhang, G. (2025). Enhancing efficiency and decision-making in higher education through intelligent commercial integration: Leveraging artificial intelligence. Journal of the Knowledge Economy, 16(1), 1546-1582.

Huang, A. Y., Lu, O. H., & Yang, S. J. (2023). Effects of artificial Intelligence-Enabled personalized recommendations on learners' learning engagement, motivation, and outcomes in a flipped classroom. Computers & Education, 194, 104684.

submitted 17.08.2025;
accepted for publication 31.08.2025;
published 30.09.2025

Contact: karpovich_vf@list.ru

European Science Review 2025,
No 7–8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 3. Engineering sciences in general

DOI:10.29013/ESR-25-7.8-25-27

INNOVATIONS IN RECYCLING AND REUSE OF HVAC SYSTEM COMPONENTS

Pogosyan David Arturikovich [1]

[1] Owner of the company NUR HVAC inc. City Belmont California USA

Cite: *Pogosyan D.A., (2025). Innovations in recycling and reuse of HVAC system components. European Science Review 2025, No 7–8.* https://doi.org/10.29013/ESR-25-7.8-25-27

Abstract

This article explores the pressing need and the growing relevance of recycling and reuse innovations within the HVAC industry. As HVAC systems contribute significantly to global energy use and material waste, innovative solutions aimed at component-level recycling are becoming a strategic priority. The article outlines current technological advancements, including smart sorting, material recovery, modular system design, and remanufacturing methods that extend the lifecycle of key HVAC components. It also analyzes business and environmental benefits, such as cost reduction, lower carbon emissions, and compliance with tightening environmental regulations. The methodology combines a review of current industry practices, case study analysis, and interviews with manufacturers and service providers. Results demonstrate that integrating recycling technologies into HVAC design and service practices leads to measurable environmental and economic gains. The study concludes by offering strategic recommendations for companies aiming to embed sustainability in their operational models through component reuse and recycling.

Keywords: *HVAC, sustainability, recycling, reuse, energy efficiency, green technology, environmental impact*

Introduction

The HVAC (Heating, Ventilation, and Air Conditioning) industry faces increasing pressure to reduce its environmental footprint. Traditional systems, after years of operation, are commonly discarded as bulk waste, adding significantly to landfill and e-waste issues. As regulations tighten and consumer awareness grows, businesses must reconsider how systems are decommissioned and components reused. This paper presents an overview of how innovation in recycling and reuse can transform HVAC.

Research objective

The goal of this research is to examine the latest technological and business innovations in the recycling and reuse of HVAC components, and to evaluate how these innovations contribute to sustainable development goals,

operational cost savings, and regulatory compliance.

Materials and methods

This article is based on qualitative analysis involving case studies of HVAC companies implementing recycling programs, a literature review of technological innovations in sustainable engineering, and expert interviews. It further includes comparative data between companies practicing reuse models versus traditional disposal methods.

Results and discussion

One notable case study conducted in Malmö, Sweden, demonstrated that after adopting adaptive reuse measures for HVAC components during the retrofit of a large urban commercial center, companies were able to reduce operational costs by approximately 30%, while also decreasing HVAC-related waste by 45%. The project focused on recovering ductwork and metal frames, refurbishing them on-site, and integrating them into updated ventilation systems. The results highlighted the viability of component-level recovery, both from economic and sustainability perspectives.

In the United States, several policy and funding initiatives are actively supporting the development of recycling and reuse infrastructure. Under the Bipartisan Infrastructure Law, the Environmental Protection Agency (EPA) launched the Solid Waste Infrastructure for Recycling Grant Program and the Recycling Education and Outreach Program. These initiatives, totaling over $117 million in available funding, aim to strengthen community recycling systems and promote awareness around materials management.

Additionally, legislative actions such as the CIRCLE Act (Cultivating Investment in Recycling and Circular Local Economies), introduced in July 2025, propose a 30% investment tax credit for recycling infrastructure projects, encouraging private and local government investment in circular economies. Another bill, the Accelerating a Circular Economy for Plastics and Recycling Innovation Act (H.R. 9676), provides federal support for technological innovation and standardization in recycling across industries, including HVAC manufacturing.

The Extended Producer Responsibility (EPR) framework has also been adopted in over 40 U.S. states. EPR laws require manufacturers to take responsibility for the post-consumer stage of their products, including HVAC components and refrigerants. This shift is promoting sustainable design practices and material recovery programs that align well with HVAC reuse models.

At the local level, programs like EnergySmart Grocer and AirCare Plus – operating in the Pacific Northwest and California – engage HVAC contractors in diagnostics, maintenance, and retrofitting efforts. These programs have collectively saved over 90 million kWh in electricity by promoting energy-efficient HVAC upgrades, further proving the impact of sustainability-focused service models.

The study found several categories of innovation driving change: modular equipment design allowing component-level replacement and reuse; AI-based sorting systems for automated material separation; and closed-loop logistics enabling parts to be recovered, refurbished, and reintegrated into new systems. One case study showed a 30% reduction in operational costs and a 45% decrease in waste when companies adopted these measures. Environmental metrics, such as carbon footprint and landfill contribution, also improved significantly. Challenges remain, such as lack of standardization across manufacturers and limited infrastructure for HVAC material recovery in some regions. Nonetheless, the overall trajectory points toward wide-scale adoption.

Conclusion

The transition from a linear to a circular model in HVAC is no longer optional but necessary. Innovations in recycling and reuse are not just environmental solutions – they are viable business strategies that offer cost efficiency, improved brand reputation, and regulatory advantages. Companies that invest in these practices today position themselves as leaders of tomorrow's green economy.

References

LUP Student Papers. HVAC Component Reuse Study in Malmö, Sweden. Retrieved from https://lup.lub.lu.se/student-papers/record/9158211
Portland Energy Conservation, Inc. EnergySmart Grocer and AirCare Plus Programs. Retrieved from https://en.wikipedia.org/wiki/Portland_Energy_Conservation
Wikipedia. Extended Producer Responsibility. Retrieved from https://en.wikipedia.org/wiki/Extended_producer_responsibility
U. S. Congress. Accelerating a Circular Economy for Plastics and Recycling Innovation Act, H.R. 9676 (2024). Retrieved from https://www.congress.gov/bill/118th-congress/house-bill/9676
The Recycling Partnership. CIRCLE Act Overview. Retrieved from https://recyclingpartnership.org/circle-act
EPA. Bipartisan Infrastructure Law: Transforming U. S. Recycling and Waste Management. Retrieved from https://www.epa.gov/infrastructure
International Energy Agency. The Future of Cooling. IEA, 2018.
United Nations Environment Programme. Cooling Emissions and Policy Synthesis Report. UNEP, 2021.
ASHRAE. HVAC&R Sustainability Roadmap. ASHRAE Publications, 2022.
U. S. Environmental Protection Agency. Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy. URL: https://www.epa.gov/smm
European Commission. Circular Economy Action Plan. Brussels, 2020.
Johnson Controls. Sustainability Report 2023.
Lennox International Inc. ESG Progress Overview. 2022.

submitted 14.08.2025;
accepted for publication 28.08.2025;
published 30.09.2025

Contact: smitm898@gmail.com

European Science Review 2025,
No 7–8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 4. Informatics

DOI:10.29013/ESR-25-7.8-28-33

THE MBERT MODEL FOR RESTORING PUNCTUATION IN UZBEK-LANGUAGE TEXTS

Hushnudbek S. Adinaev [1]

[1] Department of IT, Urgench State University, Urgench, Uzbekistan

Cite: *Adinaev H.S. (2025). The mBERT model for restoring punctuation in Uzbek-language texts. European Science Review 2025, No 7–8.* https://doi.org/10.29013/ESR-25-7.8-28-33

Abstract

This study proposes an mBERT-based approach for restoring punctuation in Uzbek-language texts. The main objective is to ensure the structural coherence of Uzbek texts by accurately reinserting punctuation marks. Using the mBERT model, we first predict punctuation for each token and then compare the prediction with any existing punctuation in the text to determine whether each mark is correctly or incorrectly placed.

Within the project, we construct a dedicated Uzbek corpus in which the relationship between every word and its surrounding punctuation is explicitly annotated. Each text is labelled according to its morphological and syntactic features. A dataset derived from this corpus is then prepared for training the model.

Keywords: *punctuation marks; NLP; mBERT model; F1 metrics*

Introduction

Punctuation marks are essential graphic tools that ensure written speech in a given language is presented correctly, expressively, and logically; they help condense text and indicate the logical-grammatical relationships between its parts (clauses and phrases). Punctuation belongs to the core system of symbols—together with letters—and differs in several respects from auxiliary symbol systems such as numerals, scientific notations, and printing marks.

The use of punctuation follows a specific system: the total number of marks, the order in which they are placed, and the principles governing their use together constitute punctuation rules. These marks convey various conceptual relationships and psychological nuances that cannot be expressed by other written means (letters, numerals, diacritics) or by linguistic units alone (words, morphemes), thereby making written text easier to understand.

The primary functions of punctuation are to indicate the semantic segmentation of speech and to clarify its syntactic structure and intonational pattern. Modern Uzbek orthography employs ten punctuation marks: the period, question mark, exclamation mark, comma, parentheses, dash, ellipsis, semicolon,

quotation marks, and colon. Most of these marks entered Uzbek writing in the second half of the 19th century, coinciding with the appearance of certain newspapers and lithographed books.

Predicting punctuation marks is a major challenge in natural-language processing (NLP). Correct and consistent punctuation greatly simplifies reading and comprehension and also enhances downstream tasks such as part-of-speech tagging, syntactic parsing, information extraction, and machine translation. Consequently, adding punctuation to transcribed speech or to texts that lack it remains a pressing problem (Pham, Q. H., Nguyen, B. T., Cuong, N. V. 2014).

Literature Review

Automatic speech-recognition (ASR) systems typically produce transcripts without punctuation and sentence boundaries. The absence of punctuation has been shown to reduce readability and to degrade the accuracy of downstream tasks such as neural machine translation, sentiment analysis, and information extraction. The authors recast punctuation restoration as a sequence-labeling problem and propose BERT-based models for English and Hungarian. Their approach extends an existing contextual model and boosts accuracy by averaging overlapping (sliding-window) predictions for each token. On the TED Talks corpus (English) and the Szeged Treebank (Hungarian), the proposed model achieved macro-F1 scores of 79.8 and 82.2, respectively, matching or surpassing previous methods (Nagy, A., Bial, B., va Ács, J., 2021).

Punctuation analysis plays a crucial role in natural language processing, requiring a model that can accurately predict proper punctuation for text preprocessing, spelling correction, grammar checking, information retrieval, and other applications. The task of accurately placing punctuation is context-dependent, which makes universal, language-independent tools less effective for this purpose. While many languages already have implemented such tools, Uzbek is a low-resource language, and, to our knowledge, there are no algorithms yet developed for analyzing or predicting punctuation in Uzbek texts. This paper proposes a rule-based algorithm and a model for analyzing periods and commas in Uzbek texts (Sharipov, M. S., Adinaev, H. S., and Kuriyozov, E. R. 2024).

The article develops an algorithm based on an N-gram statistical language model for the automatic analysis of punctuation in Uzbek texts. The author builds a corpus of 137 848 sentences (1 642 860 words) covering 30 different topics and, with a bigram model, estimates the probability of each punctuation mark, predicting the mark in place of the next word. Test results show an overall accuracy of roughly 81 percent; the F1 score for the period, comma, and question mark hovers around 0.87, while rarer marks (e.g., parentheses and quotation marks) perform slightly worse. The author suggests future work that combines the N-gram model with rule-based methods and AI approaches, and explores applying the method to other languages (Adinaev, H. S. 2025).

The article proposes a rule-based algorithm for automatically extracting interrogative sentences (questions) from Uzbek-language texts. The algorithm relies on predefined lists of interrogative pronouns (e.g., *kim* "who," *nima* "what," *qayerda* "where," *qachon* "when," *nima uchun* "why," *qanday* "how") and interrogative clitics (*-mi*, *-chi*, *-a*, *-ya*). Each word in a sentence is compared against these lists; if a match is found, the sentence is labelled "question" and added to the output list.

For evaluation, a corpus of 137 848 sentences (1 642 860 words) was compiled from 30 different text genres. Out of 7 186 genuine questions, the algorithm correctly identified 7 180, while it mistakenly labelled 554 out of 130 368 declarative sentences as questions. This yields an overall accuracy of 87.9 %, with F1 scores ranging from 76 % to 98 % across subject areas. Detailed results show that the highest accuracy was achieved on literature and mathematics texts, whereas the lowest was observed on anatomy and economics texts. The authors plan to improve accuracy by 2 hybridizing the system with N-gram language models and AI-based approaches (BiLSTM, CNN) and by expanding the corpus (Sharipov, M. S. and Adinaev, H. S. 2025).

The article describes the creation of a dedicated punctuation corpus for studying

and automatically restoring punctuation in Uzbek texts. The authors collected 30 types of material—literary works, textbooks, popular-science articles, and web content—building a corpus of 137 848 sentences (1 642 860 words). After cleaning the texts, they annotated them with ten different punctuation labels, and the frequency of each mark is presented in Table 1. Using Python scripts, they implemented functions to count the marks and save the results in CSV format. Statistical analysis shows that the period and comma are the most frequent marks, while less conventional marks—such as the dash, quotation marks, and ellipsis—occur relatively rarely. The authors plan to use the corpus in future NLP tasks such as adding punctuation to ASR outputs, developing grammar checkers, and training transformer-based models, as well as to improve accuracy through artificial-intelligence techniques (Sharipov, M. S. and Adinaev, H. S. va Yusupova, M. M. 2025).

The article offers an in-depth analysis of punctuation marks in written discourse from three perspectives: syntactic, logical-semantic, and emotional-intonational. For each of the ten primary marks-period, comma, semicolon, colon, question mark, exclamation mark, quotation marks, parentheses, dash, and ellipsis—the authors supply examples and emphasize their indispensable role in ensuring clear and precise reading. They show how incorrect punctuation can distort meaning, cause reader confusion, and disrupt written communication. Problems observed in education-such as an inability to apply rules in practice and difficulties with complex sentences—are discussed along with remedies, including interactive platforms and regular text-analysis exercises.

The final section focuses on applying modern NLP and AI technologies (ASR systems, BERT, RoBERTa, transformer models) to punctuation restoration. It cites literature confirming that hybrid approaches yield high accuracy and that combining lexical and prosodic features is effective. Thus, the study frames punctuation not only as a theoretical issue but also as a practical and technological challenge (Elov, B. B. va Sobirova, Z., 2025)

Materials and Methods

In this study, we developed a prepared dataset required for adapting the multilingual BERT (mBERT) model to the task of restoring punctuation in Uzbek texts. The process was carried out in three stages:

1. **Corpus collection —** A raw corpus of 1.5 million words was assembled from textbooks, articles, and online publications in the fields of programming, information technology, and engineering.

2. **Pre-processing —** spelling errors and non-standard punctuation were automatically corrected, Unicode normalization was applied, and all text was converted to UTF-8 encoding; sentence boundaries were detected and the text was tokenized.

3. **Annotation and formatting —** Each token was assigned a label (PERIOD, COMMA, QUESTION, EXCLAMATION, etc.); the data were stored in an mBERT-friendly layout using SentencePiece tokens and the BIO-style CoNLL format. The corpus was then split into 80 % training, 10 % validation, and 10 % test sets, with class balance preserved.

As a result, a clean and well-structured Uzbek corpus—labelled for ten core punctuation marks—has been created and is fully ready for training and evaluating mBERT or other transformer-based models. This dataset is expected to markedly improve the quality of automatic punctuation restoration in Uzbek.

3.1. The program code for creating the dataset is as follows

```
import re
from pathlib import Path
# Kirish va chiqish fayllari
RAW_FILE = “korpus.txt”
OUT_FILE = “dataset.conll”
# 10 ta tinish belgisi va ularning teg nomlari
PUNCTUATION_TAGS = {
    “.”: “PERIOD”,
    “,”: “COMMA”,
    “?”: “QMARK”,
    “!”: “EMARK”,
```

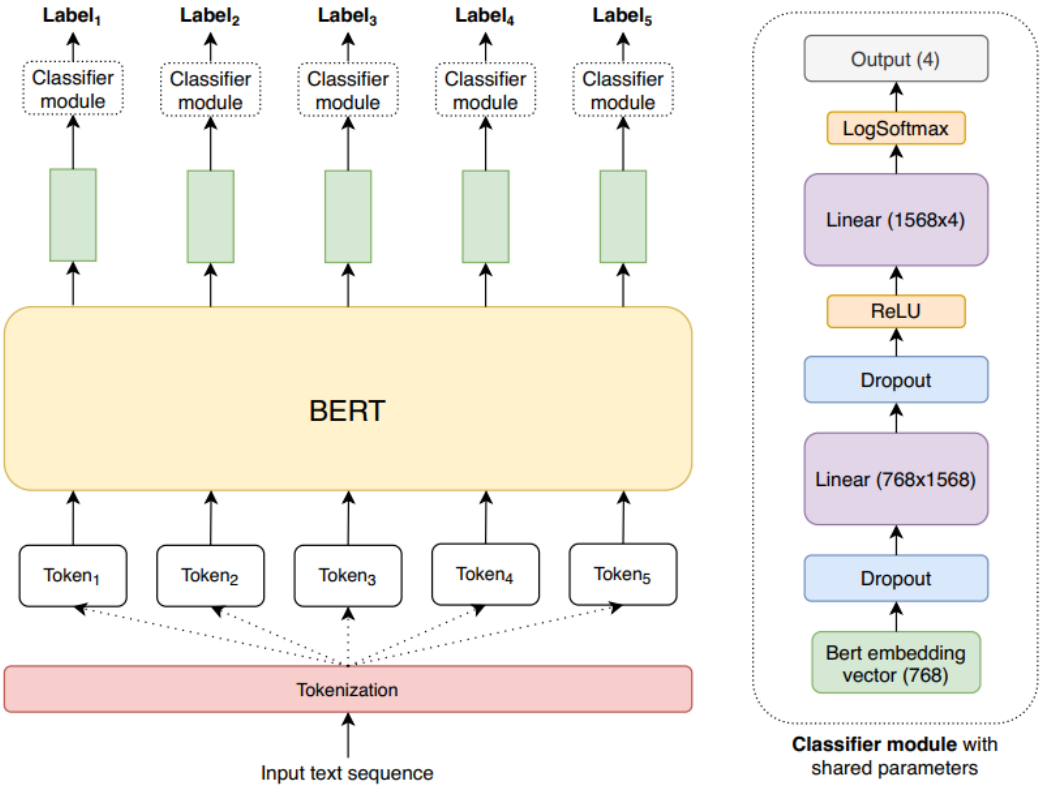
```
    “:”: “COLON”,
    “;”: “SEMICOLON”,
    “—”: “DASH”,
    “...”: “ELLIPSIS”,
    “\””: “QUOTE”,
    “(“: “PAREN”,
    “)”: “PAREN”
}
# Belgilarni uzunligi bo‘yicha tartiblab olish (masalan, “...” avvalroq)
SORTED_PUNCTS = sorted(PUNCTUATION_TAGS.keys(), key=lambda x: -len(x))
# Belgilarga mos regex (harflar orasidagi apostroflarni inobatga olamiz)
TOKEN_RE = re.compile(r”\w+[‘’‘‘‘’’]*\w*|[“+ re.escape (“”.join (SORTED_PUNCTS)) +
r”]|…”)
def tokenize_and_label(text):
    tokens = TOKEN_RE.findall(text)
    labeled_tokens = []
    for token in tokens:
        if token in PUNCTUATION_TAGS:
            if labeled_tokens:
                prev_token, _ = labeled_tokens[-1]
                labeled_tokens[-1] = (prev_token, PUNCTUATION_TAGS[token])
        else:
            labeled_tokens.append((token, “EMPTY”))
    return labeled_tokens
def process_file(in_path, out_path):
    with open(in_path, “r”, encoding=”utf-8”) as infile, open(out_path, “w”, encod-
ing=”utf-8”) as outfile:
        for line in infile:
            line = line.strip()
            if not line:
                continue
            labeled = tokenize_and_label(line)
            for word, label in labeled:
                outfile.write(f”{word}\t{label}\n”)
            outfile.write(“\n”)
if __name__ == “__main__”:
    process_file(RAW_FILE, OUT_FILE)
    print(f”[OK] Dataset yaratildi: {OUT_FILE}”)
```

3.2. The created dataset is tokenized as follows

Table 1. *Sample dataset created for mBERT*

Sequence of words	Sequence of tokens
Aksariyat	EMPTY
dasturlash	EMPTY
tillari	COMMA
xususan	COMMA
C++	COMMA
Python	COMMA
va	EMPTY
boshqalar	EMPTY
integrallashgan	EMPTY
dasturlash	EMPTY
muhiti	PAREN
IDE	PAREN
ga	EMPTY
ega	PERIOD

Figure 3.1. *The complete architecture used for punctuation restoration*



Findings and Analysis

For the experiment, a balanced Uzbek corpus of over 1.5 million words in the IT domain was selected. The resulting corpus contained 295 012 punctuation marks in total. The mBERT-based punctuation-prediction model achieved an overall accuracy of 85 percent—a noteworthy result.

Table 2. *Evaluation of models based on the F1-score*

№	Model	F1-Score
1	Rule based	0.752
2	N-gram	0.794
3	CRF	0.823
4	CRF+Rule	0.844
5	**mBERT**	**0.853**

Conclusion

Developing an Uzbek punctuation corpus is a crucial step for advancing natural-language processing (NLP) and automated punctuation systems. A properly collected and annotated corpus enables the creation of high-quality NLP models. Our punctuation corpus is a curated collection of texts designed to study and automate the use of punctuation marks. Provided in a machine-readable format, it plays a key role in tasks such as automatic punctuation restoration, speech-to-text conversion, grammar checking, and machine translation. Consequently, the corpus can bring significant benefits to AI and NLP research.

The corpus we created contains more than 1 500 000 words from IT-domain texts in Uzbek and includes 295 012 punctuation marks. As a continuation of this work, we aim to tackle Uzbek punctuation analysis with artificial-intelligence models and achieve even higher accuracy in future experiments.

References

Pham, Q.H., Nguyen, B.T., Cuong, N.V. (2014). Punctuation Prediction for Vietnamese Texts Using Conditional Random Fields // *ACML Workshop: Machine Learning and Its Applications in Vietnam (MLAVN 2014)*. – P. 1–9.

Nagy, A., Bial, B., va Ács, J., (2021). Automatic punctuation restoration with BERT models, *arXiv* preprint arXiv: 2101.07343, Jan.

Sharipov, M.S., Adinaev, H.S., and Kuriyozov, E.R. (2024). Rule-Based Punctuation Algorithm for the Uzbek Language, in International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices, EDM, – P. 2410 – 2414. doi: 10.1109/EDM61683.2024.10615061.

Adinaev, H.S. (2025). "Punctuation Analysis of Uzbek Texts Based on the N-gram Model," Electronic Journal of Actual Problems of Modern Science, Education and Training, – vol. 2025. – No. 2. – P. 2025. ISSN 2181-9750.

Sharipov, M.S.va Adinaev, H.S. (2025). Development of models for punctuation analysis of Uzbek language texts, Bulletin of TUIT: Management and Communication Technologies, – vol. 1. – no. 4. 2025. ISSN 2181-1083.

Sharipov, M.S. and Adinaev, H.S. (2025). O‘zbek tili matnlarida so‘roq gaplarni aniqlashning qoidaga asoslangan algoritmini ishlab chiqish, Management and Future Technologies, – vol. 2. – no. 1. – P. 182 – 189. Mar. 2025.

Sharipov, M.S. and Adinaev, H.S. (2025). Shartli tasodifiy maydonlar modeli asosida o‘zbek tili matnlarini punktuatsion tahlil qilish, Al-Farg‘oniy avlodlari elektron ilmiy jurnali, – vol. 1. – no. 2. – P. 66–70, 2025.

Sharipov, M.S. and Adinaev, H.S. va Yusupova, M.M. (2025). O‘zbek tili matnlarida punktuatsion tahlil qilish uchun korpus yaratish, Development of Science, – vol. 2. – no. 3. – P. 128–133, Mar. 2025. ISSN 3030-3907.

Elov, B.B. va Sobirova, Z. (2025). Tinish belgilarining matndagi ahamiyati va vazifalari, *Proc. V Xalqaro ilmiy-amaliy konferensiya "Kompyuter lingvistikasi: muammolar, yechim, istiqbollar"*, – vol. 1. – no. 1. – P. 540–547, May 2025.

Sharipov, M. and Vičič, J. "Dataset of Uzbek verbs with formation and suffixes," *Data in Brief*, – vol. 61. 2025. doi: 10.1016/j.dib.2025.111731.

Sharipov, M., Kuriyozov, E., (2024). Yuldashov, O., and Sobirov, O. "UzbekVerbDetection: Rule-based Detection of Verbs in Uzbek Texts," in *Proc. of the 2024 Joint Int. Conf. on Computational Linguistics, Language Resources and Evaluation (LREC-COLING 2024)*, – P. 17343–17347.

submitted 12.07.2025;
accepted for publication 26.07.2025;
published 30.09.2025

Contact: hushnudbek.adinaev@gmail.com

European Science Review 2025,
No 7–8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

DOI:10.29013/ESR-25-7.8-34-42

DEVELOPMENT OF A CONTEXT-FREE GRAMMAR (CFG)-BASED MODEL AND ALGORITHM FOR PREDICATE IDENTIFICATION IN SIMPLE UZBEK SENTENCES

Maksud S. Sharipov [1]

[1] Department of Computer Sciences, Urgench State University named after Abu Rayhan Biruni

Cite: *Sharipov M.S. (2025). Development of a Context-Free Grammar (CFG)-based model and algorithm for predicate identification in simple Uzbek sentences. European Science Review 2025, No 7–8.* https://doi.org/10.29013/ESR-25-7.8-34-42

Abstract

Syntactic parsing is one of the most critical stages within existing analysis methods in Natural Language Processing (NLP). It identifies sentence and phrase types and exposes the grammatical relations between words. Because Uzbek belongs to the agglutinative family of languages, its morphological and syntactic analysis requires specially tailored approaches. Uzbek is as a low-resource language, and – up to now – there are still no sufficiently robust models for syntactic parsing of its texts. In the syntactic analysis of Uzbek, the most critical challenge is to identify the predicate (verb phrase) among the sentence constituents. Therefore, this article develops an algorithm and model for predicate identification in sentences based on Context-Free Grammar (CFG), along with accompanying IDEF0 and IDEF1X models. Using these models, the architecture of the proposed system is presented in an overall schematic: its functional capabilities are described with the IDEF0 model, while the relationships among objects are depicted with the IDEF1X model. In addition, a rule-based algorithm for detecting the predicate in Uzbek sentences has also been implemented. During the execution of the algorithm, the program first calls the pre-developed Python library **UzbekTagger** to determine the part of speech of the word under examination, and then invokes the **UzbekLemmatizer** library to identify the word's affixes. Consequently, a dedicated database that classifies Uzbek words by their parts of speech has also been created.

Keywords: *SYNTACTIC PARSING, PREDICATE, NLP, IDEF0, IDEF1X*

Introduction

IDEF0 (Integration Definition for Function Modeling) is a functional modeling methodology used to represent the functions, activities, and processes of a system or organization. It's a graphical language that helps in understanding, analyzing, and improving complex processes. IDEF0 is particularly useful for decomposing complex systems into manageable components and visualizing the relationships between functions.

IDEF1X (IDEF1X Extended) is a methodology for constructing relational information structures. It is a type of methodology used to

describe relationships between objects and is typically used to model relational databases relevant to the system under consideration (Czukanova O. A., 2015).

In contemporary Uzbek linguistics, syntactic analysis – namely, the investigation of the syntactic relations within a sentence – is regarded as highly important. Before any analysis can proceed, the sentence's principal constituents must first be identified, a requirement that highlights how critical it is to locate the predicate.

Syntax (from the Greek *syntaxis* – "arrangement, construction") is fundamentally the branch of linguistics that investigates the sentence. Because a sentence is ultimately based on the free combination of words, the regularities that govern word combination and phrase formation likewise fall within the scope of syntactic inquiry. The study of word-group structures is therefore an integral part of sentence theory and cannot be examined in isolation from it.

Within the sentence, the **predicate** is the obligatory, central constituent; other elements (subject, object, attribute, adverbial modifier, etc.) may be absent, yet no sentence can be constructed without a predicate. The predicate, which serves as the nucleus of the sentence, is the word (or complex) that realizes the grammatical categories of affirmation/negation, tense, modality, and person/number – that is, the categories of predicativity. Accordingly, an utterance lacking a predicate is classified as structurally incomplete in Uzbek discourse.

If a sentence lacks a predicate, it is considered structurally incomplete in Uzbek. The predicate constitutes a constructive sentence component whose realization hinges on its own grammatical system – the categories of predicativity. Hence, the predicate invariably exhibits a complex internal structure (Sayfullayeva R. R., Mengliyev B. R., Boqiyeva G. H., Qurbanova M. M., Yunusova Z. Q., Abuzalova M. Q., 2009).

Therefore, locating the predicate is one of the principal challenges in the syntactic analysis of Uzbek texts. In the sections that follow, we critically examine the models and algorithms that have so far been proposed for syntactic parsing.

The most widely used formal system for modeling constituent structure in English and other natural languages is the Context-Free Grammar, or CFG. Context- free grammars are also called Phrase-Structure Grammars, and the formalism is equivalent to Backus-Naur Form, or BNF. The predicate forms the core semantic nucleus of a sentence, expressing the subject's action or state. In NLP systems, accurately detecting the predicate is vital for fully understanding sentence meaning and for subsequent language-processing stages.

Several characteristics of Uzbek complicate this task:

- Agglutinativity: Grammatical meaning is largely conveyed through suffixes. By attaching a series of suffixes to the verb stem, one marks categories such as tense, mood and person.
- Negative affix: The morpheme -ma- inside the verb creates a negative predicate.
- Modal elements: Words such as kerak "must/necessary," mumkin "may/possible," and lozim "needful/obligatory" can combine with a verb to form a complex predicate.
- Free word order: Although the canonical order is Subject-Object-Verb (SOV), constituents may appear in various positions; the predicate is not always sentence-final.

Taking these factors into account, a context-free grammar (CFG)-based approach has been chosen for predicate detection. CFG rules allow the sentence structure to be formally specified and algorithmically parsed, making it possible to isolate constituents such as the predicate with precision. The approach builds on earlier work that parsed simple sentences with a general CFG, but here the grammar rules focus solely on extracting the predicate.

Goal of the article – to develop CFG rules targeted exclusively at identifying predicates in Uzbek simple sentences and to test them with a parsing algorithm. The proposed method is expected to benefit several NLP applications – including grammar checking, machine translation and sentence-structure analysis – because reliably isolating the predicate is crucial in all these processes.

Literature Review

Although research on automatic predicate detection in Uzbek is still limited, the

last few years have seen the first steps in this direction. To begin with, Rakhmonova's work on parsing simple sentences with a CFG framework (Raxmonova M. A., 2023). provides a solid foundation for identifying the predicate thanks to her grammar's flexibility, even though the predicate was not treated as a separate module in that study.

The issue of formally representing Uzbek verb forms and person-number suffixes as trees is addressed in part by Sharipov & Sobirov's lemmatization system (Sharipov M. va Sobirov O., 2022) and by Sharipov et al.'s punctuation algorithm (Sharipov M. S., Adinaev H. S., Kuriyozov E. R., 2024), which lay the groundwork for rigorously separating the verb stem from its affixes. Maksud and colleagues, in the "UzbekVerbDetection" project (Sharipov M., Kuriyozov E. R., Yuldashev O., Sobirov O., 2024), proposed a rule-based approach that achieved an F-score of 0.89 in the predicate-identification stage, yet they did not model the structure of simple sentences fully at the CFG level.

For modeling predicates in Turkic languages via CFG, Dönmez & Adalı's study on Turkish (Dönmez İ., Adalı E., 2018) and Zafer's general Turkic syntactic parser (Zafer H. R., 2011) offered important methodological precedents for other agglutinative languages such as Uzbek. In Kazakhstan, Sharipbay et al. (Sharipbay A., Yergesh B., Razakhova B., Yelibayeva G., Mukanova A., 2019) demonstrated the effectiveness of CFG rules by treating the predicate in Kazakh simple sentences through an ontological model.

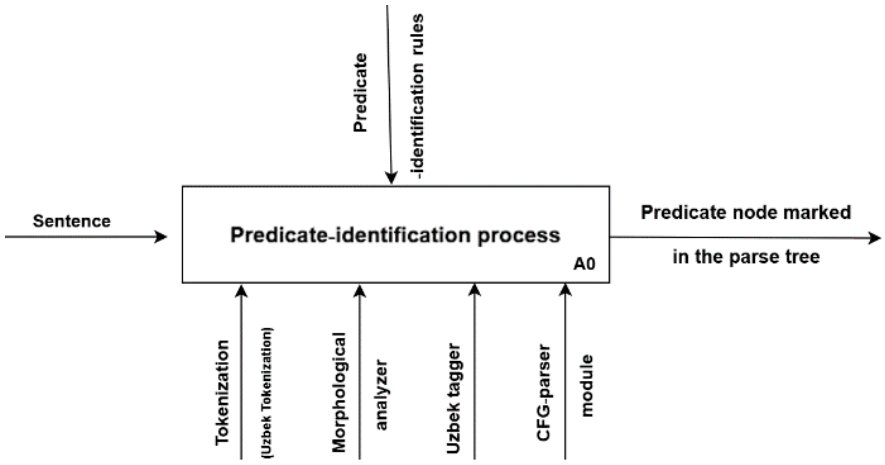
From lexical and syntactic perspectives, Gribanova's analysis of predicate formation and ellipsis mechanisms (Gribanova V., 2020) and recent studies on "complex predicate" constructions (Kornfilt J., 2012) show that the Uzbek predicate can consist not only of a main verb but also of modal words and copulative elements. Moreover, research in the SPMRL series on morphologically rich languages (Seddah D. va boshq., 2013) underscores the need to enrich CFGs by accounting for predicate–argument relations and affix interaction.

In sum, existing work has focused on verb detection or general parsing; there is still no dedicated methodology that marks only the predicate in simple Uzbek sentences using CFG. Our study aims to fill this gap by creating a specialized set of predicate rules – covering person-number, tense, negation and modal elements – and testing them with the Earley algorithm.

Methodology

The structure of the proposed system for predicate identification in simple Uzbek sentences outlines the core components and their interactions within the model. The system is designed to process Uzbek text inputs, identify sentence constituents, and accurately detect the predicate using a Context-Free Grammar (CFG)-based approach. Each component of the system performs a specific function, ensuring seamless integration for effective syntactic parsing. The overall architecture of this system is detailed below.

Figure 1. *General IDEF0 Diagram of the Predicate-Identification Process*

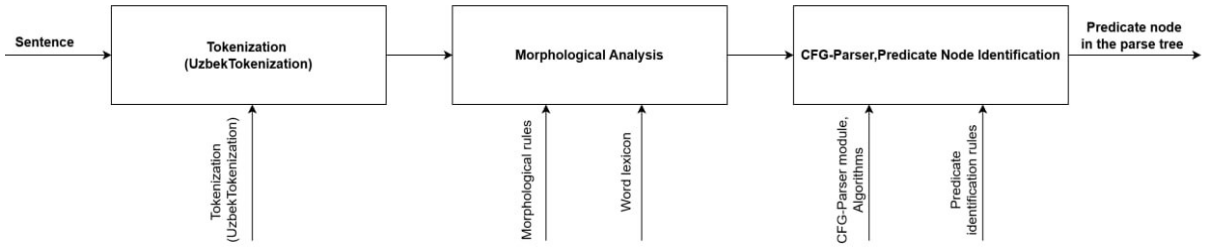


A0: Predicate Identification in Uzbek Sentences

- **Node Name**: Predicate Identification in Uzbek Sentences;
- **Node Number**: A0;
- **Input**: Uzbek simple sentences;
- **Output**: Identified predicates;
- **Control**: CFG rules, part-of-speech tags, affix rules;
- **Mechanism**: Computer, Python libraries (UzbekTagger, UzbekLemmatizer), Algorithms.

This general IDEF0 diagram illustrates the interconnected processes, with each node representing a distinct functional component of the predicate identification system.

Figure 2. *Interconnected IDEF0 Diagram of the Predicate Identification System*



A1: Tokenizing and Tagging Words

- **Node Name**: Tokenizing and Tagging Words;
- **Node Number**: A1;
- **Input**: Uzbek sentence text;
- **Output**: Tagged words;
- **Control**: UzbekTagger library, tokenization algorithm;
- **Mechanism**: Computer, Software, Algorithm.

A2: Lemmatization and Affix Analysis

- **Node Name**: Lemmatization and Affix Analysis;
- **Node Number**: A2;
- **Input**: Tagged words;
- **Output**: Lemmatized words with affix information;
- **Control**: UzbekLemmatizer library, affix detection rules;
- **Mechanism**: Computer, Software, Algorithm.

A3: Predicate Detection

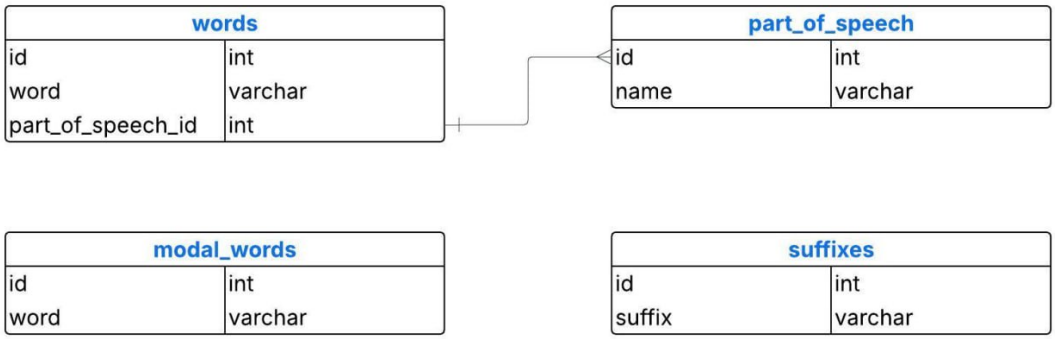
- **Node Name**: Predicate Detection;
- **Node Number**: A3;
- **Input**: Lemmatized words with affix information;
- **Output**: Identified predicate;
- **Control**: CFG rules, predicate identification algorithm;
- **Mechanism**: Computer, Software, Algorithms.

The IDEF0 diagram sequences these processes, providing detailed information on inputs, outputs, controls, and mechanisms for each step. Based on this structure and the IDEF0 diagrams, the predicate identification system has been developed. The system is designed to be scalable, with potential integration into web-based or standalone NLP applications.

IDEF1X Model of the Predicate Identification Database

The predicate identification system employs a relational database to store and manage linguistic data. The database supports the classification of Uzbek words by part of speech, affix structures, and modal elements, which are essential for accurate predicate detection. The core entities in the database include words, part-of-speech categories, affixes, and modal words. The physical model of the database is presented below.

Figure 3. *IDEF1X Information Model of the MPTQDV Database*



This database schema is designed to support linguistic analysis tasks, such as word classification, part-of-speech tagging, and morphological processing. It contains a total of four main tables: words, part_of_speech, modal_words, and suffixes.

1. words

This table stores words and their associated part of speech. It contains 81,346 records.

Column Name	Data Type	Description
Id	Int	Unique identifier for each word.
Word	Varchar	The actual word (e.g., «run», «book»).
part_of_speech_id	Int	Foreign key referencing part_of_speech(id).

2. part_of_speech

This table defines the grammatical categories (parts of speech) for words.

Column Name	Data Type	Description
Id	Int	Unique identifier for each part of speech.
name	Varchar	The name of the part of speech (e.g., noun, verb, adjective).

3. modal_words

This table contains modal verbs or auxiliary words, which express modality (e.g., necessity, possibility).

Column Name	Data Type	Description
Id	Int	Unique identifier for each modal word.
word	varchar	The modal word itself (e.g., «must», «can», «should»).

4. suffixes

This table stores suffixes used in morphological analysis.

Column Name	Data Type	Description
Id	int	Unique identifier for each suffix.
suffix	varchar	The suffix text (e.g., «-ing», «-ed», «-s»).

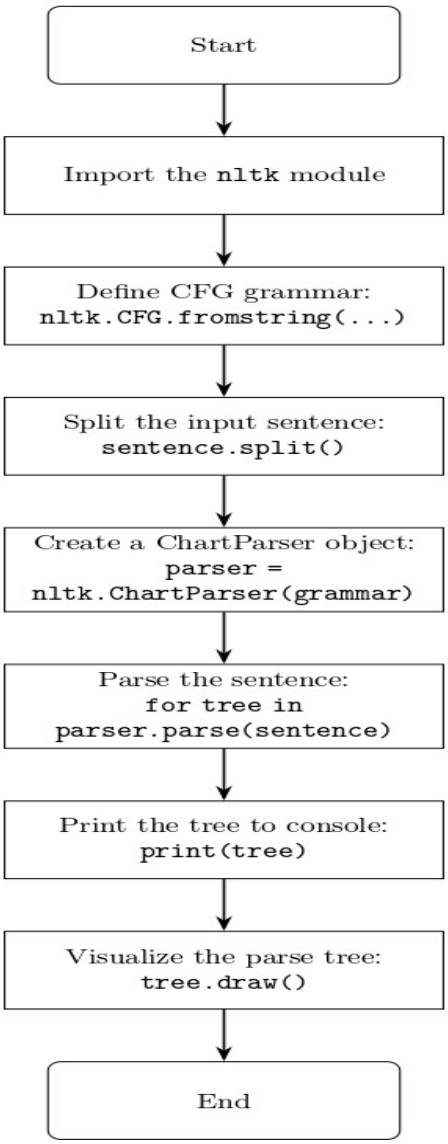
Experiments and Results

To evaluate the performance of the proposed CFG-based predicate identification model, an Uzbek corpus containing 25,000 simple sentences was selected. The corpus was curated to ensure diversity, covering 20 different domains (e.g., news, literature, academic texts), with approximately 1,250 sentences per domain. This balanced dataset was used to test the model's ability to accurately detect predicates in varied linguistic contexts.

The corpus included 18,430 predicates, annotated manually to serve as the ground truth for evaluation. Each sentence in the raw corpus was processed to create two versions: one retaining all grammatical and morphological features for evaluation, and another preprocessed version where words were tokenized and tagged using the UzbekTagger library, then lemmatized with the UzbekLemmatizer library. The preprocessed version was fed into the model for predicate identification.

The model's performance was assessed using standard NLP metrics: precision, recall, and F1-score. The results showed that the model achieved a precision of 0.91, a recall of 0.88, and an F1-score of 0.89 for predicate identification across the corpus. These metrics indicate robust performance, particularly in handling complex predicates involving modal elements and negative affixes, which are characteristic of Uzbek's agglutinative nature.

Figure 4. *Stages of the rule-based predicate identification and prediction algorithm*



Algorithm. *Algorithmic representation of the proposed rule-based predicate identification/prediction method*

```
import nltk
# Define a Context-Free Grammar (CFG) for parsing simple Uzbek sentences to identify
predicates
# The grammar is specified using NLTK's CFG format, with rules for sentence structure
and predicate forms
grammar = nltk.CFG.fromstring("""
# Top-level rule: A sentence (S) consists of a BEGIN marker, an OTLIQISM (noun
phrase), and a KESIM (predicate)
S -> BEGIN OTLIQISM KESIM
# KESIM (predicate) can be one of eight possible forms (Q1 to Q8), covering various
predicate constructions
KESIM -> Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8

# Q1: Predicate form with a verb (FEL), a connector (+), a predicate-forming suffix
(HNY), a modal word (MODAL), and an END marker
Q1 -> FEL "+" HNY MODAL END
# Q2: Predicate form with a non-verb (NONFEL), a connector (+), a person/number suffix
(KEQ), and an END marker
Q2 -> NONFEL "+" KEQ END
# Q3: Predicate form with a verb (FEL), a connector (+), a tense/linking form (TLF),
and an END marker
Q3 -> FEL "+" TLF END
# Q4: Predicate form with a non-verb (NONFEL), a connector (+), a tense/linking form
(TLF), and an END marker
Q4 -> NONFEL "+" TLF END
# Q5: Predicate form with a verb (FEL), a connector (+), a tense marker (ZMN), a per-
son marker (SHXSN), and no END (incomplete rule)
Q5 -> FEL "+" ZMN "+" SHXSN
# BEGIN and END markers denote the start (*) and end (#) of a sentence

BEGIN -> "*"
END -> "#"
# NONFEL represents non-verb parts of speech, including nouns (OT), adjectives (SI-
FAT), adverbs (RAVISH), etc.

NONFEL -> OT | SIFAT | RAVISH | SON | OLMOSH | RAVSH | KOMAKCHI | BOGLOVCHI | YUKLAMA
| UNDOV
# HNY: Predicate-forming suffixes commonly used in Uzbek verbs
HNY -> "ish" | "sh" | "v" | "uv" | "moq" | "mak"
# MODAL: Modal words that modify the predicate, indicating necessity, obligation,
etc.
MODAL ->"kerak" | "shart" | "lozim" | "darkor"
# KEQ: Person/number suffixes for non-verb predicates
KEQ -> "man" | "san" | "dir" | "miz" | "siz" | "dilar"
# TLF: Tense or linking forms used in predicates
TLF -> "edi" | "ekan" | "emish" | "emas"
# ZMN: Tense markers for verbs, indicating present, past, or future
ZMN -> "a" | "di" | "yapti" | "gan" | "moqda" | "yotibdi" | "yap" | "ajak" | "moq" |
"moqchi" | "sa"
# SHXSN: Person markers indicating the subject (1st, 2nd, 3rd person, singular/plu-
ral)
SHXSN -> "man" | "san" | "dir" | "ti" | "di"

# OTLIQISM: Noun phrase, here specifically defined as "Toshkentga nega" (to Tashkent,
why)
OTLIQISM -> "Toshkentga" "nega"

# FEL: Verb, limited to "bor" (to go) in this example
FEL -> "bor"
""")

# Define the input sentence to parse, split into tokens
```

```
# Example sentence: “* Toshkentga nega bor + ish kerak #” represents a marked Uzbek
sentence with a predicate
sentence = “* Toshkentga nega bor + ish kerak #”.split()

# Create a ChartParser object using the defined CFG to parse the sentence
parser = nltk.ChartParser(grammar)
# Iterate through all possible parse trees generated by the parser
   # Each tree represents a valid syntactic structure of the sentence according to
   the CFG
   for tree in parser.parse(sentence):
   # Print the parse tree to the console for inspection
   print(tree)
   # Visualize the parse tree in a graphical window using NLTK’s draw method
   tree.draw()
```

Conclusion

This article presents the development of a model and algorithm based on Context-Free Grammar (CFG) for identifying predicates in Uzbek sentences. The study utilized IDEF0 and IDEF1X models to describe the system's functional capabilities and relationships between objects. Implemented in Python, the system leverages the UzbekTagger and UzbekLemmatizer libraries to determine parts of speech and analyze affixes. Additionally, a specialized database was created to classify Uzbek words by their parts of speech. The system was tested on a corpus of 25,000 Uzbek sentences, achieving a high F1-score of 0.89 for predicate identification. The CFG-based rules were designed to account for the agglutinative features of Uzbek, such as affixes, negative forms, and complex predicate structures involving modal words. The use of IDEF0 and IDEF1X models facilitated a clear depiction of the system's functional and data structures, creating a robust foundation for scalability and integration with other NLP applications. Moreover, a database containing 81,346 words, classified by parts of speech, modal words, and affixes, was established, serving as a valuable resource for future linguistic analyses. The rule-based algorithm was provided as open-source, enabling its use by other researchers. However, the study has limitations, as it does not address predicate identification in highly complex sentences, which may restrict its broader applicability. In conclusion, this research introduces an effective CFG-based model and algorithm for predicate identification in Uzbek, marking a significant step in the syntactic analysis of the language. While the results demonstrate the system's practical applicability, further improvements can be made by testing on complex sentences and larger corpora, as well as incorporating machine learning techniques. Future work aims to develop models that encompass all punctuation marks and broader linguistic features.

References

Sayfullayeva R. R., Mengliyev B. R., Boqiyeva G. H., Qurbanova M. M., Yunusova Z. Q., Abuzalova M. Q. (2009). Hozirgi o‘zbek adabiy tili. O‘quv qo‘llanma. – T., «Fan va texnologiya», – 416 p.

Sharipov M. va Sobirov O., (2022). Development of a Rule-Based Lemmatization Algorithm Through Finite State Machine for Uzbek Language, *CEUR Workshop Proceedings*, – P. 154–159. CEUR-WS

Sharipov M., Kuriyozov E. R., Yuldashev O., Sobirov O., (2024). UzbekVerbDetection: Rule-Based Detection of Verbs in Uzbek Texts, *Proc. LREC–COLING 2024*, Torino, – P. 17343–17347. ACL Anthology

Zafer H. R., (2011). *A Generic Syntactic Parser for Turkic Languages*, MSc thesis, Fatih University, Acik Bilim.

Sharipov M. S., Adinaev H. S., Kuriyozov E. R., (2024). Rule-Based Punctuation Algorithm for the Uzbek Language,” Proc. 25th IEEE Int. Conf. of Young Professionals on Micro/Nanotechnologies and Electron Devices (EDM), – P. 2410–2414. CoLab.

Dönmez İ., Adalı E., (2018). Context Free Grammar for Turkish, Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi, – vol. 22. – no. 2. – P. 552–561. Home.

Sharipbay A., Yergesh B., Razakhova B., Yelibayeva G., Mukanova A., (2019). Syntax Parsing Model of Kazakh Simple Sentences," ACM International Conference Proceeding Series, ACM Digital Library.

Gribanova V., (2020). Predicate Formation and Verb-Stranding Ellipsis in Uzbek, Glossa: a journal of general linguistics, – vol. 5. – no. 1. Art. 124. Glossa.

Kornfilt J., (2012). Complex Predicates in Turkish, in The Oxford Handbook of Turkish Linguistics, Oxford University Press, – P. 319–333. JSTOR

Seddah D. va boshq., (2013). "Overview of the SPMRL 2013 Shared Task: A Cross-Framework Evaluation of Parsing Morphologically-Rich Languages," Proc. 4th Workshop on Statistical Parsing of Morphologically-Rich Languages (SPMRL), Seattle, – P. 146–182. ACL Anthology

Raxmonova M. A., (2023). *O'zbek tilidagi sodda gaplar uchun sintaktik parsing modeli*, Toshkent: Navoiy avlat O'zbek tili va adabiyoti universiteti,.

Czukanova O. A. (2015). Metodologiya i instrumentarij modelirovaniya biznes-processov: uchebnoe posobie – SPb.: Universitet ITMO, – 100 p.

submitted 04.08.2025;
accepted for publication 18.08.2025;
published 30.09.2025

Contact: maqsbek72@gmail.com; ixtiyoravezmatov07@gmail.com

European Science Review 2025,
No 7–8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 5. Medicine

DOI:10.29013/ESR-25-7.8-43-49

SURGICAL REHABILITATION OF MALIGNANT TUMORS OF THE ORAL MUCOSA USING THORACO-PECTORAL AND DELTOPECTORAL FLAPS

Konstantine Mardaleishvili [1]***, Tamar Baramidze*** [1]

[1] Tbilisi Oncology Scientific Center. Department of Head and Neck Oncology, BAU International University Batumi

Cite: *Mardaleishvili K., Baramidze T. (2025). Surgical Rehabilitation of Malignant Tumors of the Oral Mucosa Using Thoraco-Pectoral and Deltopectoral Flaps. European Science Review 2025, No 7–8.* https://doi.org/10.29013/ESR-25-7.8-43-49

Abstract

Malignant tumors of the oral mucosa are the sixth most common among all oncological diseases and the third most common among malignant head and neck tumors. This disease often affects young patients. After treatment, vital functions such as opening the mouth, swallowing, chewing, eating, and speaking either decrease, or are limited, or disappear altogether, which causes deep psychological trauma to the person. A large part of people with this pathology are isolated from both society and social activities. The defects formed after surgical treatment are often incompatible with life without plastic and reconstructive operations.

The existing difficulties make it necessary to assess the expected results of the chosen treatment method before using it, to calculate the degree of restoration of vital functions and the risks accompanying the conduct of reconstructive and reconstructive operations.

Keywords: *Malignant tumors of the oral mucosa, reconstructive and reconstructive operations. Vital functions. Combined and complex treatment. Defects formed after surgery, skin autograft, deltopectoral flap, and thoracopectoral flap*

Introduction

Malignant tumors of the oral mucosa include tumors of anatomically different localization and neighboring organs, such as the buccal mucosa, tongue, floor of the mouth, mucosa covering the alveolar ridge of the upper jaw, hard and soft palate, uvula, tonsils and palatine arches, mucosa covering the alveolar ridge of the lower jaw, Salivary glands.

Malignant tumors of the oral mucosa account for 2–4 percent of all malignant tumors and 20 percent of malignant tumors of the head and neck. It is equally common in both men and women, with a slight predominance in men over 60 years of age, although it is not uncommon in patients over 40 years of age. Despite the fact that tumors of this localization are considered tumors of visual

localization, (Figure 1,.Figure 2) the rate of active detection of patients in the early stages does not exceed 10 percent, and 71 percent of tumors are diagnosed in the third or fourth stage of the disease. It is important that only 3–4 percent of patients are detected as a result of preventive examinations.

Figure 1.

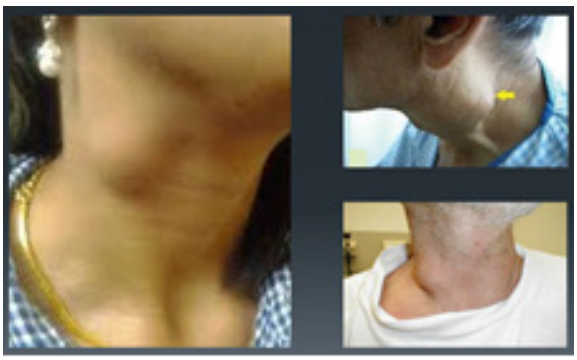
Figure 2.

Treatment of malignant tumors of the oral mucosa is radiation therapy, chemotherapy and surgical treatment in various sequences or combinations.

The effects of combined or complex treatments, single or multiple antitumor effects, subsequent tumor progression, repair of defects formed after surgery, the use of grafts, and improvement in the patient's quality of life after plastic and reconstructive surgery remain the subject of ongoing research.

The issue of metastasis of malignant tumors of the oral mucosa is characterized by distinct features, both in terms of prevalence and frequency, as well as localization. Figure 3 presents the types of regional lymphogenous metastasis of malignant tumors of the oral mucosa.

Figure 3.



Distant metastasis is also characterized by no less peculiarities. Presumably, there should be a computed tomography of the lungs, where there is a unilateral metastasis and where there is a bilateral metastasis.

The anatomy and physiology of the oral mucosa performs such indispensable functions as chewing, breathing, swallowing, speech and aesthetic functions. Any pathology in the oral cavity creates unfavorable conditions for adaptation in terms of labor, social and medical conditions. And the defects formed after treatment are incompatible with life without plastic reconstructive operations.

The aim of the study is to evaluate the effectiveness of the use of deltopectoral and thoraco-pectoral autografts for the surgical treatment of malignant tumors of the oral mucosa, in particular, for the purpose of one-time plastic surgery of defects formed after resection of half of the tongue, resection of the floor of the mouth, and resection of the buccal mucosa.

The task of the study is to determine the type of surgical treatment of malignant tumors of the oral mucosa at a certain stage of combined or complex treatment. Also, to determine the effectiveness of the method based on the viability of the flaps selected for the restoration of defects formed after the operation, which is carried out in the postoperative period, on the second, fourth and seventh days after the operation, using Doppler to assess the patency of the flap's feeding blood vessels. The flap surface is assessed by visual inspection every day until the completion of revascularization.

At the Tbilisi Oncology Scientific Center, 511 patients with a diagnosis of malignant tumors of the oral mucosa were treated from 2021 to 2025.

Among them, 115 (22.5%) were women and 396 (77.49%) were men.

The age ranged from 32 to 80 years, of which 36 (7.04%) patients were under 40 years of age, 207 (40.51%) patients were between 40 and 60 years of age, and 278 (54.40%) patients were over 60 years of age.

According to localization, squamous cell carcinoma of the buccal mucosa was detected in 113 (22.11%) cases, squamous cell cancer of the tongue was diagnosed in 337 (65.94%) patients, and malignant tumor of the floor of the mouth was verified in 61 (11.93%) patients. 342 (67%) of the patients mentioned chronic mechanical irritants, improperly adjusted dentures, damaged, non-removable orthopedic structures, or fractured roots as the etiological factors. The presence of.

The first stage of malignant tumor of the oral mucosa T1 N0 MO was diagnosed in 104 (20.34%) cases.

The second stage T2N0M0 – in 121 (23.67%) cases.

The third stage T1-2-3N1M0 was detected in 225 (44.03%) patients.

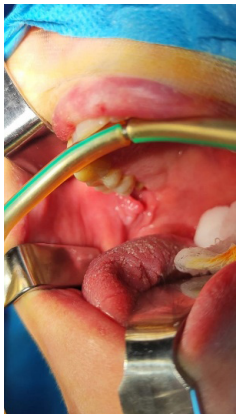
The fourth stage T1-2-3-4N1-2-3M1 was detected in 61 (11.93%) patients. Accordingly, regional lymphogenous metastasis was detected in 286 (55.96%) patients, and distant metastasis was diagnosed in 61 (11.93%) cases.

All patients underwent sequential clinical-laboratory examination, cytological and morphological examination of the neooperative material. Neck lymph nodes, Ultrasound examination of the submandibular and submental lymph nodes to detect regional lymphogenous metastases. Computed tomography of the chest, abdomen, and brain to detect distant metastases.

Of the examined patients 27(5,28%) had a history of physical treatment of tumor formation. 156(30,72%) of the patients fad undergone chemoradiation treatmrnt three years before shouing signs of tumor progression.Surgical treatment Wide excisionof the tumor single-stage plastic surgery, using local tissues, tree to four years before the combined treatment was performed in 71(13,89) patients-fig4–5Figure N5 shows the patient with a tumor on the buccal mucosa resulting from mechanical trauma to the upper and lower impacted wisdom teeth over athree year period.A wide excision of the tumor was performed with a sing local tissues after surgical wxtraction of impacted wisdom teeth.

Figure 4.

Figure 5.



Of the 121 patients with stage II, 72 (59.50%) patients underwent combined treatment – surgical treatment in the first stage of treatment and chemoradiation treatment in the second stage. Surgical treatment includes both primary tumor excision, namely resection of half of the tongue, resection of the floor of the mouth, fragmentary resection of the lower jaw with one-time reconstruction of the defect, as well as prophylactic lymphadenectomy with Vanakh's operation or fascial-fusiform dissection of the lymph nodes of the neck in full volume.

Figure 6.

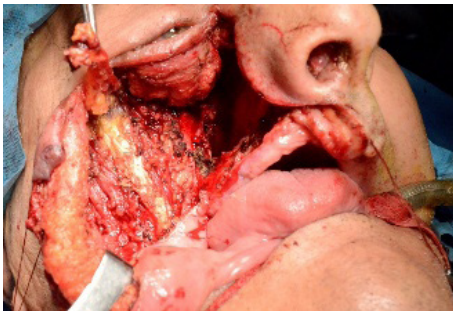


Figure 7.

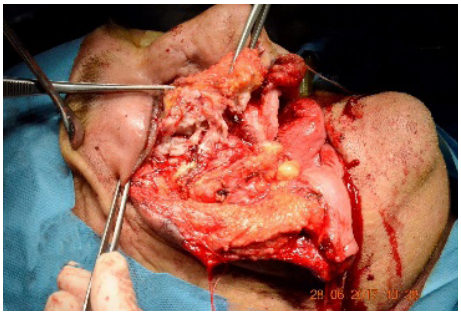


Fig. N6, Fig. N7, Fig. N8, Fig. N9, Fig. N10 picture shows a patient with a tumor of the floor of the mouth that spread to the middle and anterior third of the tongue and infiltrated the anterior frontal region of the mandible. A resection of the floor of the mouth, a resection of half of the tongue, a fragmentary resection of the mandible were performed, and a thoracodorsal flap was used for the purpose of a single-stage plastic surgery of the postoperative defect, through which the integrity of the floor of the mouth was restored. Figure #10 shows the excised specimen, and #9 shows the floor of the mouth restored with a thoracodorsal flap.

The Resection of the buccal mucosa, resection of the right upper jaw, resection of the body of the zygomatic bone, and resection of the lower orbital wall. Wanach type surgery was performed in 27 (22.31%) cases. Figure N11–12 – A patient with a malignant tumor of the buccal mucosa, which infiltrated the body of the zygomatic bone, the lower orbital wall and the upper jaw bone, is presented.

Figure 8.

Figure 9.

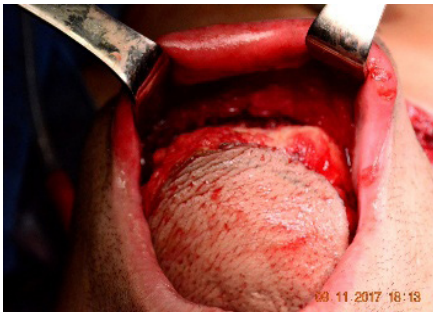


Figure 10.

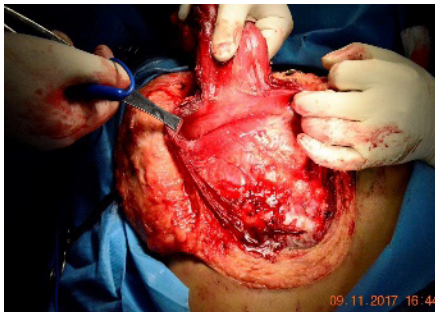


Figure 11.

Figure 12.

Partial resection of the tongue, neck lymphadenectomy – Wanach type operation, and extirpation of the salivary gland were performed in 22 (18.18%) cases. Fig. N11, Fig. N12.

During the third stage, the treatment is combined or complex in nature; the combined treatment of patients with the third stage, in addition to surgical treatment, includes radiation and chemotherapy. In particular, radiation therapy is carried out in the form of radiation therapy combined with chemotherapy in a radical program, with a total focal dose of 70 Gy. For chemotherapy, six infusions of simple new adjuvant chemotherapy were used every eighth day. Carboplatin 150 mg was used for one course. 6 vials of Carbocel 150 mg were used for one course.

Surgical treatment of the third stage group of patients is a combined-extended operation, which involves partial or complete resection of both the primary tumor and the surrounding organs and intervention on the regional lymphatic collector. In particular, in the case of malignant tumors of the buccal mucosa, these were the masticatory muscles, the alveolar ridge of the upper jaw or the lower pole of the parotid gland, and in the case of malignant tumors of the floor of the mouth or tongue, resection of half of the tongue was required, resection of the floor of the mouth together with the upper – suprahyoid muscle group of the hyoid bone. Extirpation of the submandibular salivary gland and resection of half of the lower jaw with or without exarticulation. Fig. N13, Fig. N14, Fig. N15, Fig. N16, Fig. N17.

Figure 13.

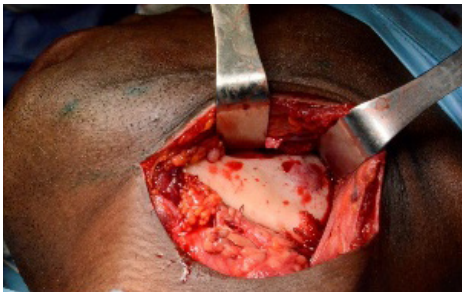
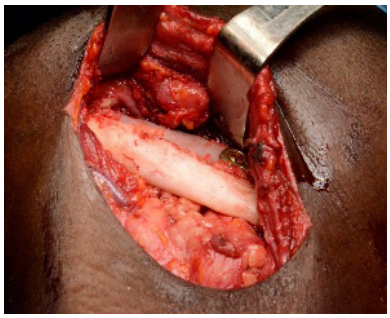


Figure 14.

Figure 15.

Figure 16.

Figure 17.



The picture shows a patient with a malignant tumor of the tongue, spreading to the floor of the mouth and the lower jaw. After surgical treatment, the defect formed was repaired using a thoraco-pectoral flap. Figure 15–16 shows a rib projected onto the defect formed after fragmentary resection of the lower jaw – a defect repaired using a thoraco-dorsal flap. Figure 17 shows the excised specimen.

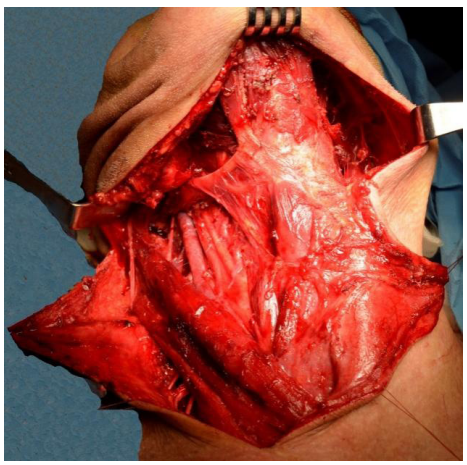
In terms of regional metastasis, a Wanach operation or a full fascial-fusiform dissection of the cervical lymph nodes was performed.

In order to repair the formed defect, in 121 (53.77%) of 225 patients, a delto-pectoral or thoraco-pectoral flap was used.

Figure 18.

Figures N18, N19, N20 and N21 show a patient with a malignant tumor of the floor of the mouth that extends to the alveolar ridge of the mandible and the tongue. A resection of half of the tongue, a resection of half of the mandible, and a resection of the floor of the mouth were performed. The formed defect was repaired using a thoraco-pectoral flap. Figures N21, N22, N23, N24. The integrity of the mandible was restored using a titanium implant. Figures 25–26.

Figure 19.



Resection of the lower half of the mandible was performed in 59 (26.22%) cases. After resection of the lower half of the mandible, a titanium implant was used in 27 (12%) cases. Resection of the upper jaw

and alveolar ridge was performed in 33 (14.66%) cases, and resection of the lower jaw with exarticulation in 12 (5.33%) cases.

Figure 20.

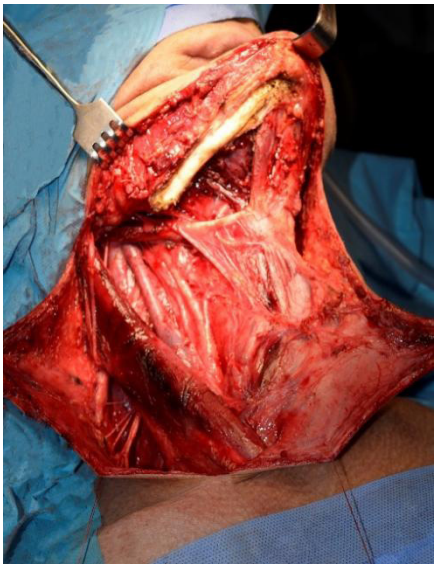
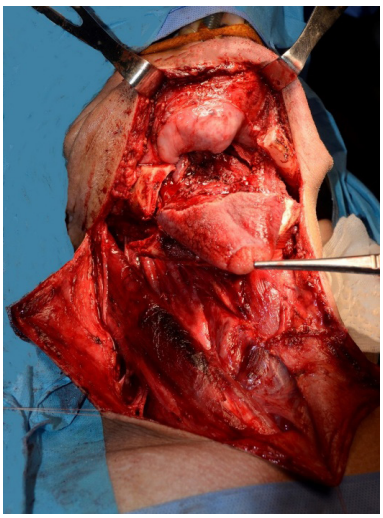


Figure 21.

Figure 22.



It should be noted that after performing operations of this scale, the vast majority of patients have not undergone orthopedic treatment in terms of restoring the dental row and dentition, which, of course, reduces the ability to chew, swallow, speak, eat and directly reduces the quality of life.

In the group studied by us, signs of tumor progression after treatment were noted only in 9 (4.11%) patients, where treatment continued with chemotherapy, and 4 (1.77%) patients underwent palliative treatment. The case of thoraco-pectoral flap necrosis was observed in two (0.88%) patients.

The group with the fourth stage mainly underwent complex treatment. Where chemoradiation treatment was performed in the first stage of treatment, and surgical treatment in the second stage in the form of combined-extended surgery, in 53 (86.88%) out of 61 cases, and in 8 (13.11%) cases the patient underwent only chemoradiation treatment or palliative treatment. And in order to restore the formed defect, a skin – muscle – mucosa – bone autograft was used using a microsurgical technique. Free autograft necrosis was observed in 2 (3.77%) out of 53 cases.

The progression of the tumor process was not observed in this group of patients, although the quality of life and vital functions of the patients were very low, or rather unsatisfactory.

As for the issue of distant metastasis, depending on whether the metastasis was subject to resection or not, the issue of surgical treatment or palliative treatment was decided. According to the ESMO recommendation, in the case of localized processes, we mainly used radiation therapy or surgical treatment in isolation from the above methods. The effectiveness of these methods is equally effective in terms of local regional control. However, conclusions were still drawn based on retrospectral clinical analysis, taking into account the individual situation.

According to our study, defects formed after surgical treatment of malignant tumors of the oral mucosa without the use of deltopectoral and thoracopectoral flaps are incompatible with life. In the treatment of stage I tumors, chemo-radiation treatment is the leading method. As for surgical treatment, it is better to use organ-preserving treatment; surgical treatment should be used only in rare cases. In addition, the thickness

of the tumor should be consistently studied and taken into account as a prognostic factor in tumor progression in the treatment of stage II tumors.

In the second stage, it is also better to perform chemo-radiation treatment in the first stage and only in the second stage to decide on surgical treatment.

As for the third stage, the treatment is complex, with chemo-radiation in the first stage and surgical treatment in the second stage in the form of combined-extended operations. The guideline data should be inserted here.

It is necessary to refine the issues of postoperative rehabilitation of such patients, where the issue of using titanium implants or dental implants in the remaining jaw bone during the plastic-reconstructive recovery process should be highlighted, which will allow us to conduct postoperative rehabilitation of such patients and significantly improve the quality of life.

References

Ariyan, S. (1979). The pectoralis major myocutaneous flap: a versatile flap for reconstruction in the head and neck. Plast Reconstr Surg.

Bakamjian, V.Y. (1965). A two-stage method for pharyngoesophageal reconstruction with a primary tube constructed from a pectoralis major myocutaneous flap. Plast Reconstr Surg.

Cordeiro P. G., Santamaria E. (2000). A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. Plast Reconstr Surg.

Boyd J. B., Mulholland S., Davidson J., et al. (1996). The outcome of mandibular reconstruction in the elderly patient. Plast Reconstr Surg.

submitted 10.07.2025;
accepted for publication 24.07.2025;
published 30.09.2025

Contact: tamarbaramidze5@gmail.com

European Science Review 2025,
No 7–8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 6. Pedagogy

DOI:10.29013/ESR-25-7.8-50-53

FORMATION OF A PRESCHOOLERS' COMMUNICATIVE COMPETENCE WHEN LEARNING ENGLISH IN THE PROCESS OF PLAY ACTIVITIES

Ranokhon Nishonova [1]

[1] Uzbek National Pedagogical University, Uzbekistan, Tashkent

Cite: *Nishonova R. (2025). Formation of a Preschoolers' Communicative Competence When Learning English in the Process of Play Activities. European Science Review 2025, No 7–8.* https://doi.org/10.29013/ESR-25-7.8-50-53

Abstract

This article is devoted to the disclosure of theoretical and practical aspects of the development of a preschooler's communicative competence in the process of learning English through play activities. In this article we will discuss features of preschool age, the role of play in learning a foreign language, as well as specific methods that contribute to the formation of communication skills.

Keywords: *globalization of society, informatization of society, language abilities, communicative competence, interpersonal communication, intercultural communication, teaching methods, natural language environment, learning process*

Introduction

The modern world requires a person not only to speak their native language, but also to be able to communicate effectively in foreign languages. In the context of globalization and informatization of society, learning English is becoming not just a desirable, but a necessary skill. Increasingly, parents and teachers are realizing the importance of starting learning a foreign language early, since preschool age is the most favorable period for the formation of language abilities. The child's brain has a unique plasticity during this period, which allows him to easily learn new sounds, words and grammatical structures.

However, the key goal of learning a foreign language at preschool age is not so much to master grammar or an extensive vocabulary, but rather to develop communicative competence. Communicative competence is the ability and willingness to carry out interpersonal and intercultural communication in a foreign language with native speakers, as well as to use a foreign language as a means of learning about the world and self–expression. For preschoolers, this means the ability to understand simple English, respond to it, and express their thoughts and desires at a basic level in situations appropriate to their age.

Traditional teaching methods aimed at schoolchildren often prove ineffective for toddlers. Preschoolers learn through action, exploration, and most importantly, through play. Play is the leading activity at this age, a natural and organic way of learning about the world and developing all mental processes. That is why play activity becomes a central element in the process of developing a preschooler's communicative competence when learning English. It allows you to create a comfortable, motivating and natural language environment in which the child does not feel pressure, but perceives the learning process as an exciting adventure.

The concept of "communicative competence" is one of the key concepts in modern methods of teaching foreign languages. It was introduced into scientific use by the American linguist Dell Hymes in 1972 as a response to the limitations of purely linguistic competence (knowledge of the rules of language). Hymes argued that it is not enough to know grammar and vocabulary for effective communication; it is also necessary to understand how and when to use language in various social contexts. In the context of learning a foreign language, communicative competence includes several interrelated components:

Linguistic Competence: Knowledge of linguistic units (phonetics, vocabulary, grammar) and the rules of their functioning. For preschoolers, this means recognizing and reproducing basic sounds, words, simple phrases, and sentences.

Sociolinguistic Competence: The ability to choose and use linguistic means in accordance with the communication situation, the social status of the interlocutors, their roles and cultural norms. For example, knowing how to greet an adult or a peer, how to ask for something politely.

Discourse Competence: The ability to make coherent and logical statements, understand and create texts (in this case, short dialogues, simple stories). This is the ability to connect sentences into a single whole, to maintain a conversation.

Pragmatic Competence: The ability to use language to achieve specific communicative goals (for example, to ask, offer, thank, express agreement/disagreement).

Strategic Competence: The ability to use different strategies to compensate for insufficient knowledge or skills in the communication process. For example, to ask again, to use gestures, facial expressions, to simplify a statement.

Features of preschool age and learning a foreign language. Preschool age (from 3 to 7 years old) is a unique and critically important period in a child's development, which has a significant impact on the process of learning a foreign language. Understanding these features allows teachers and parents to build effective teaching methods.

The sensitive period for language acquisition: Preschool age is considered the sensitive (most favorable) period for language acquisition. At this time, the child's brain has high neuroplasticity, which allows him to easily learn the phonetics, intonation and rhythm of foreign speech, as well as form new neural connections responsible for language functions. Children are able to imitate sounds and accents much more accurately than adults. The main activity is play: Play is the main way for preschoolers to explore the world. Through play, the child learns social roles, develops imagination, emotional sphere, fine and large motor skills, as well as cognitive processes. Learning embedded in play activities is perceived by the child naturally, without coercion and stress. Involuntary attention and memory: Preschoolers' attention and memory are predominantly involuntary. This means that the child remembers information better, which causes him an emotional response, is interesting and is included in active activities. Monotonous exercises and cramming are ineffective.

Visual-imaginative thinking: A preschooler's thinking is visual-imaginative. He needs to see, touch, and act with objects in order to understand and remember information. The use of visual aids (pictures, toys, gestures, facial expressions) is a prerequisite for successful learning. Emotionality: Preschoolers are very emotional. Positive emotions contribute to a better assimilation of the material and the formation of a stable interest in the language. Negative emotions, on the contrary, can cause rejection and block the learning process. Fatigue and the need to change activities: Children quickly get tired

of monotonous activities. Classes should be short (15–25 minutes), dynamic, with frequent changes in activities (singing, moving, playing, drawing).

The need for movement: Preschoolers needs constant movement. The inclusion of physical activity (physical training, outdoor games) in the learning process not only relieves stress, but also promotes better memorization of vocabulary and phrases. Egocentrism: In the early stages of preschool age, children focus on themselves. It is important that the language material is related to their direct experience, interests and environment. Imitative learning: Children learn language by imitating adult speech. It is important that the teacher or parent be a model of correct and clear English speech for the child.

Results

Given these features, it becomes obvious that learning English at preschool age should be as close as possible to the natural process of mastering a native language – through immersion in the language environment, repeated repetition in various contexts, active interaction and, of course, through play.

The role of play activities in English language teaching

Play is not just entertainment, but the leading activity of a preschooler, his main way of learning about the world, development and self–expression. In the context of learning a foreign language, the game acquires special importance, becoming a powerful tool for the formation of communicative competence.

Naturalness and organicity: Play is a natural environment for a child. He feels comfortable, free and safe in the game. Learning embedded in the game is perceived as a continuation of natural activities, and not as a forced occupation. This reduces the psychological barrier and fear of mistakes.

Motivation and interest: The game is inherently exciting. It arouses the child's keen interest, curiosity and desire to participate. During the game, children are ready to make efforts, repeat the material repeatedly, without noticing fatigue. The positive emotions associated with the game contribute to the formation of a sustained interest in the English language. Creating a natural language environment: The game allows you to simulate real-life situations in which language is used to achieve specific goals. In the game, the child does not just memorize words, but uses them to communicate, express their thoughts, requests, and emotions. This contributes to the formation of situational and contextual memory.

Development of all components of communicative competence:

Linguistic: Repeated repetition of vocabulary and grammatical structures in game situations helps to consolidate them.

Sociolinguistic: Role-playing teaches the use of language in accordance with social roles and situations.

Discursive: Games that require building dialogues and short stories develop the coherence of speech.

Pragmatic: Goal-setting games (for example, "find an object", "ask for directions") teach you how to use language to achieve specific goals.

Strategic: During the game, children learn to overcome communication difficulties using the means available to them.

Removing the psychological barrier: In the game, the child is not afraid to make a mistake, as it is perceived as part of the gameplay, and not as a failure in the lesson. This creates a favorable atmosphere for experimenting with the language.

Development of involuntary attention and memory: Due to emotional involvement in the game, information is absorbed involuntarily and remembered more firmly. Integrated development: The game promotes not only language, but also the general development of the child: it develops imagination, thinking, memory, attention, fine motor skills, social skills, emotional intelligence. Enabling Movement: Many games involve physical activity, which meets preschoolers' need for movement and helps relieve tension.

Thus, the game is not just a methodical device, but a fundamental principle of organizing English language teaching at preschool age. It allows you to make the learning process exciting, effective and as close as possible to the natural process of language acquisition.

The development of a preschooler's communicative competence when learning English

in the process of play is one of the most promising and effective areas in modern preschool pedagogy. The unique features of preschool age – sensitivity to language, the leading role of play, involuntary attention and memory, emotionality – dictate the need to build the educational process on the principles of naturalness, fascination and activity. The game, being an organic form of cognition of the world for the child, acts not just as a methodical device, but as the foundation on which the entire process of mastering the English language is built. The effectiveness of the process is significantly increased if the subject-development environment is competently organized, rich in visual, audio and game materials that stimulate the child to use English independently. Monitoring and evaluation of the development of communicative competence in preschool age are informal, based on systematic observation of the child in natural play situations and aimed at supporting his progress, rather than strict control.

Thus, the purposeful and systematic use of play activities in the process of learning English at preschool age allows not only to lay a solid foundation for further language education, but also contributes to the harmonious development of the child's personality, the formation of his cognitive interests, social skills and self-confidence. The early start of learning English through play opens up new opportunities for preschoolers to communicate and explore the world, making them more open and ready for the challenges of modern global society.

References:

Vereshchagina, I. N., Rogova, G. V. (2008). Methods of Teaching English at the Initial Stage in Secondary School. Moscow: Education. (Although the book is focused on primary school, many principles are applicable to preschool education).

Gal'skova, N. D., Gez, N. I. (2004). Theory of Teaching Foreign Languages: Lingvodidactics and Methodology. Moscow: Academy.

Komarova, T. S. (2005). Children's Creativity: What Develops and How to Stimulate It. Moscow: Mosaic-Synthesis. (Useful for the section on the subject-developing environment and materials for creativity).

Passov, E. I. (2000). Communicative Foreign Language Education: The Concept of Developing Individuality in the Dialogue of Cultures. Lipetsk: LSPU.

submitted 21.08.2025;
accepted for publication 04.09.2025;
published 30.09.2025

Contact: gulyamovazarina@mail.ru

European Science Review 2025,
No 7–8
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 7. Philology and linguistic

DOI:10.29013/ESR-25-7.8-54-56

SEMANTIC MODELING IN MODERN PROSE TEXT

Javanshir Yusifli [1]

[1] Department of Literary Theory, Azerbaijan National Academy of Sciences, Nizami Ganjavi Institute of Literature

Cite: *Yusifli J. (2025). Semantic Modeling in Modern Prose Text. European Science Review 2025, No 7–8.* https://doi.org/10.29013/ESR-25-7.8-54-56

Abstract

In a fictional text, semantic modeling covers not only the content plan of the literary-fictional example, but also, as a rule, indicates the framework in which the idea and structure are located. "Semantic model" is, first of all, dynamics and rhythm, that is, a simple movement, let us say, can convey to the reader the "alarm signal" sounded in the first sentence, in the broadest possible sense. A semantic model is also a concept that discovers existing connections between a literary work and other literary and artistic examples by revealing them. A semantic model is a category that expresses the author's style, thanks to which, for example, we can say that "A. Camus could have written this story this way and ended it this way". How does the spectrum of meanings expressed and encapsulated in a literary work affect the meanings outside the work? Undoubtedly through this "semantic modeling."

Keywords: *semantic model, literary text, rhythm, alarm signal, artistic form*

Introduction

The structure of fictional prose is a complex concept that includes all the inputs and outputs to the world of reality and spirit in a prose text; and "structure" also means the realization and expression of spatio-temporal relations in the text. The term "narrative" also defines the structure of a fictional text. Any idea in a prose work and the structure itself as a whole are in various structural-semantic models through which the idea put forward by the author against the reality is realized.

This idea can be explained as follows: in a fictional prose text, any complex of ideas (say, the sense of smell in Patrick Süskin's novel Perfumer) becomes comprehensible after passing through a whirlpool of the most diverse phenomena in various semantic forms; the semantic model of "perfumes library" is formed on its basis. It can be concluded that after the semantic model is fully integrated into the plan of expression, the work becomes "impersonal", leaving the author's hands and entering the reader's world.

The main part

Genre thinking, genre logic

As a continuation of the above idea, the "perfumes library" is an object that explains the literary text on a metaphorical plane, going beyond its boundaries, before becoming a semantic model in relation to the work and its ideas. This in itself is a very important element for understanding the literary text. That is, the ideas flowing within the frame and the metaphorical plane calling that boundary, forming an opposition to the ideas within the frame. This situation turns Süskind's novel "The Perfumer" into a global aesthetic phenomenon. In our opinion, in a good prose work, along with all these different means, the word itself is "repelled", as they say, it goes into the background, and only the movement of the internal rhythm of the story is felt. The reader reads and feels the work precisely with this rhythm, with the energy given by this feeling. The reader's feeling of the artistic example is an aesthetic phenomenon that should be discussed separately. There are works in Azerbaijani prose that substantiate this aesthetic phenomenon. The expression "background" was not used by chance. The brightness of the word, the "scatter of light", the "spurt of color" of the scene create conditions for a primitive narrative structure, or rather, it conditions the writer to be a prisoner of the word from beginning to end. Remember Albert Camus's novel "The Stranger", or the novel "The Plague". The strengthening and weakening "amplitude" of the internal rhythm of the simple rat story creates conditions for the word to be forgotten at every turn, and for the reality in the work to be relegated to another world, and even to the background. The work exists because it tells of events that everyone knows, in other words, that have happened to everyone (Yusifli Javanshir, 2018, 17).

We witness this in Etimad Başkeçid's story "Veyil Valley". The word standing on the border reveals only the "useful" aspects of the description, in this story the movement of the internal rhythm curve is traced in the background, the chronotope "does not appear" on the word, as they say, it comes out of the background of the story, its internal rhythm, every event and object, let's say, even ordinary rain, has a dual function – it is both the cause of something and the result of something. In this sense, Etimad does not continue his poetry in prose, and in both cases you witness his different attitude to LANGUAGE. There is no need for special models in this research system, but this is conditioned by the method of approaching the story and its description. And then the narrative strategy: "... Let this consist in the fact that they catch several rats, put them in a box and do not feed them for a long time. The rats, somehow exhausted by hunger, finally choose one of their own, bite and eat. Then it is the turn of another and so in the end only one rat remains (the big rat I just saw was just one of them) ... » (Bashkechid Etimad).

Etimad's story "Gather the Sun for Me" is undoubtedly not a new line in his work, such a writing method has already been established, how can we say, in his, for example, "Veyil Valley" and other stories, that is, in any of Etimad's stories (unlike his novel-!), a mystical aura is created at a specific point in the development of events, and then, one after the other, perhaps eye-opening events occur. In this story, due to the aspect we have emphasized above, the description, moving from fragment to fragment, can create a very clear image, sometimes related to the mental state of the person. At the moment when the description occurs and "dies" (ends-!) That image occupies the entire territory of the world in the story. Thanks to this, a more different and deeper-dimensional fragment appears, and their mutual conditioning is resolved by the logic of the transition between fragments. Pay attention to the way the "Professor" suddenly finds himself in one of these moments: "... He was strangely confused, I tell you. As soon as he opened his mouth, it was clear that the person was not himself. Yes, they may not see that a person is smart for a lifetime, but when he is crazy, they notice it in two minutes. The professor was afraid of going crazy at his age, and even more so of being called crazy. He came to this specialized hospital in the mountains, on the advice of his friends, to balance himself and, if possible, get rid of the trouble he had fallen into" (Bashkechid Etimad, 2023, 13).

In this sense, Roland Barthes's thoughts may be relevant: "The pathfinder (symbolizing the boundary between meanings) does

not always have to play the role of a boundary between commonly known and commonly accepted opposites (materialism and idealism, reformism and revolution, etc.), but instead it always and everywhere draws a barrier between rules and exceptions to those rules. A rule is an abuse of something and an exception is a pleasure. This is why in some cases it is necessary to side with even the mystics, their cults, which constitute the exception. All exceptions are possible if only we get rid of the tedious repetition of rules (sociality, stereotypes, formalism, in short, everything that strengthens language)" (Yusifli Javanshir, 2018).

Conclusion

The attitude at the level of a literary text to an event in history (remote, near or far – it does not matter) is always a risk. Unlike ordinary events, the facts of historical progress have a "real" attitude towards them, people who witnessed them. When these facts are mentioned in a work of fiction, the "author's position" is momentarily forgotten and waves of controversy come flooding over the work.

It is possible to express the attitude to any event in different genres. You can write a narrative, a novel, or a story. The essence of this event that arises within the work of fiction can be different in each genre mold. That is, in each genre, a semantic model can arise in different dimensions.

References

Bashkechid Etimad. Veyil Valley. https://manera.az/index.php?newsid=11779
Bashkechid Etimad. (2023). Gunesh topla menim uchun. «Adebiyyat qazeti», – No. 19. – P. 12–13.
Barthes Roland. The Judgment of Language. The Death of the Writer. The Birth of the Reader. URL: https://news.milli.az/culture/140101.html
Yusifli Javanshir. (2018). Text. Sign. Meaning. – Baku, Mutarjim.

submitted 20.07.2025;
accepted for publication 04.08.2025;
published 30.09.2025

Contact: djavanchir@gmail.com

Contents