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## RESEARCH ON THE HYDROBIOCHEMICAL STATE OF LAKE LISI WATER

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**რეზიუმე**

ტბების ძლიერმა დაბინძურებამ ანთროპოგენური და ბუნებრივი ფაქტორების მეშვეობით, შეიძლება გამოიწვიოს ევტროფიკაციის პროცესი - წყლის ბინადრებში ბიოგენური ელემენტების დაგროვება. ევტროფიკაცია კვლავ რჩება წყლის ხარისხის მართვის მთავარ პრობლემად შიდა წყლებისთვის: როგორც ტბებისთვის, ასევე წყალსაცავებისთვის. საქართველო წყლის რესურსებით მდიდარი ქვეყანაა, მათ შორის 856 ტბაა. არსებული ტბებიდან ერთერთია ქალაქ თბილისის ქვაბულში მდებარე ლისის ტბა, რომელიც ჩვენი კვლევის საგანია. ის წარმოადგენს მოსახლეობისათვის საუკეთესო დასასვენებელ, რეკრიაციულ ზონას. ჩატარებული იქნა ლისის ტბის მონიტორინგი. შესწავლილი იყო მისი ფიზიკურ-გეოგრაფიული, კლიმატური მდგომარეობა. ფიზიკურ-ქიმიური კვლევების შედეგად გამოვლენილი იქნა,რომ წყალი ხასიათდება მაღალი მარილიანობით, ორგანული დაბინძურებით, ჟანგბადდეფიციტით და ევტროფიკაციის ნიშნებით, ხოლო მიკრობიოლოგიური ანალიზმა გვიჩვენა, რომ ყველა სანიტარულ მაჩვენებელში ფიქსირდება გადაჭარბება და წყალი ეპიდემიოლოგიურად საფრთხის შემცველია. დადგინდა, ლისის ტბის წყალი არ აკმაყოფილებს რეკრიაციულ მოთხოვნებს და საჭიროებს შესაბამის გარემოსდაცვით და სარეაბილიტაციო ღონისძიებებს.

**Abstract**

Severe pollution of lakes through anthropogenic and natural factors can lead to the process of eutrophication - the accumulation of biogenic elements in aquatic organisms. Eutrophication remains the main problem of water quality management for inland waters: both lakes and reservoirs. Georgia is a country rich in water resources, including 856 lakes. One of the existing lakes is Lake Lisi, located in the Tbilisi Basin, which is the subject of our study. It is the best resting and recreational zone for the population. Its physical-geographical and climatic conditions were studied. As a result of physical-chemical studies, it was revealed that the water is characterized by high salinity, organic pollution, oxygen deficiency and signs of eutrophication, while microbiological analysis showed that all sanitary indicators are exceeded and the water is epidemiologically dangerous. It was determined that the water of Lake Lisi does not meet recreational requirements and requires appropriate environmental protection and rehabilitation measures.

**საკვანძო სიტყვები:** ლისის ტბა, რეკრეაციული ზონა, მონიტორინგი, კვლევა, ანალიზი, დაბინძურება.

**Keywords**: Lisi Lake, recreational zone, monitoring, research, analysis, Pollution.

### Introduction

Georgia is rich in water resources, including 856 lakes. Pollution of water bodies can occur from various sources. In recent years, water consumption has increased sharply in both urban and rural areas. Accordingly, water pollution has increased and has become widespread, which is due to the mixing of polluted water into rivers and lakes, which damages the ecosystem and threatens the existence of small lakes. [1,2].

Lakes, both natural and man-made, are subject to urban, industrial, agricultural, and other impacts. Severe pollution of lakes through anthropogenic and natural factors can lead to the process of eutrophication

- the accumulation of biogenic elements in aquatic organisms [3].

Eutrophication remains a major water quality management problem for inland waters: both lakes and reservoirs. The way to stop the degradation is to stop the sources of nutrients and accelerate the recovery in lakes with the help of technologies. Eutrophication in the initial stages leads to an increase in the biological productivity of water bodies, and then to a progressive lack of oxygen and, consequently, to the massive death of living organisms. Many measures have been developed regarding eutrophication, including the Sustainable Development Goals of the United Nations Development Program (UNDP) [ 6, 9].

Approaches to preventing and reversing eutrophication include minimizing pollution from point sources such as sewage and agriculture, as well as other non-point sources of pollution. In addition, the introduction of bacteria and algae inhibitory organisms, which also help reduce nitrogen pollution, in turn controls the growth of cyanobacteria, which is the main source of algal blooms.

A global practice on watershed restoration has been developed – the UN Decade of Ecosystem Restoration. Key themes include holistic approaches, lake-specific diagnostics, and integrated management to address pollution, sedimentation, and changing demands, with efforts increasingly integrating climate adaptation and circular economy principles [10, 11].

**Characterization of the research object**

The object of the study is Lake Lisi, monitoring its pollution. Lake Lisi is located in the Tbilisi Basin, northwest of the city. Lisi - height above sea level - 624 m., lake area - 0.47 $km^2$, basin area - 16.1 $km^2$, maximum depth -4.0 $km^2$, average depth -2.60 m, lake volume - 1.22 million. $M^3$. The Lisi Lake basin is separated from the surrounding areas by low and medium-height hilly terrain. The lake is of a closed type and currently, the surface area of the lake varies from 40-50 ha. The development of the lake area began a long time ago. Currently, Lake Lisi is one of the most popular recreation and areas health in the city. In 2007, the new Tbilisi Hippodrome was opened near it, covering an area of 31 hectares and is a favorite place for horse riding enthusiasts. In recent years, the shoreline of Lake Lisi has been rehabilitated: a recreation area has been renovated, a beach has been arranged, and a coastal path has been laid. A new thermal bath has been opened (there are several thermal springs around the lake). Fish are bred in the lake. After the improvement of Lake Lisi, the flow of citizens, water sports enthusiasts, and fishing enthusiasts has significantly increased, and accordingly, anthropogenic pollution is expected to increase [8]. Based on the above, it is important to monitor the pollution of Lake Lisi.

**Methods and analysis results**

For the complex research conducted on Lake Lisi (hydrochemical, physicochemical, and microbiological), a modern, field-based mobile device, the latest laboratory equipment, and internationally recognized methods were used. Due to the goals and objectives of the study, only licensed ISO standards were used. According to its nutrition, it is a mixed-type water body, fed by rain, snowmelt, and groundwate [4.5.7].

The water level maintains high levels in spring, and low levels in autumn. In summer, the water is warm, with a maximum temperature of 28 °C. In winter, an ice edge and sometimes an ice cover appear on the lake. The water is brackish (mineralization 2060 mg/l).

The organoleptic characteristics of water were determined, one of the important indicators of which is temperature, which to some extent shows the speed and direction of water quality changes. Affects the physical, chemical and biological processes taking place in the reservoir, which actually determine the oxygen regime of water and the intensity of the self-purification process [12].

An informative indicator of water quality is the pH value. It determines the natural properties of water and, at the same time, is an indicator of its pollution. In clean waters, the pH value varies within the range of 6.5 - 8.5. The water of Lake Lisi is characterized by weak alkalinity. The pH value varies within the range of pH = 8.00 - 8.27 . Therefore, the content of heavy metals in dissolved form is not expected in the water, which is also evident from the research results. From the sanitary characteristics of water quality, we identified: biological oxygen demand (BOD), dissolved oxygen and biogenic compounds: ammonium salts, nitrites, nitrates and phosphates. The analysis results are presented in Table 1.

Table 1.

Organoleptic and physicochemical indicators of Lake Lisi

| # | Name | Unit | Measurement results | MPC | Method used |
|---|---|---|---|---|---|
| 1 | Temperature °C | ˚C | 12 | | |
| 2 | Smell | Bali | Odorless | 2 | ISO 6658 |
| 3 | Turbidity | NTU | 5,2 | 3,5 | ISO 7027 |
| 4 | Electrical conductivity | μS/cm | $30,4 \cdot 10^{-2}$ | | **ISO 7888:1985** |
| 5 | Mineralization | ppm or mg/l | 2060 | 300-1200 | Total Dissolved Solids - TDS |
| 6 | pH | | 7,8 | | ISO 10523.94 |
| 7 | Dissolved oxygen ($O_2$) | mg/l | 6,4 | 4 -6 | ASTM D888 |
| 8 | Ammonium ($NH_4^+$) | mg/l | 0,51 | 0,39 | ISO 7150-1:2010 |
| 9 | Nitrite ($NO_2^-$) | mg/l | 0.014 | 1,0 | ISO 10304-1:2007 |
| 10 | Nitrate ($NO_3^-$) | mg/l | 0.045 | 10 | |
| 11 | Phosphate ($PO_4^{3-}$) | mg/l | 0.145 | 3,5 | |
| 12 | Sulfates ($SO_4^{-2}$) | mg/l | 2035.16 | 500 | |
| 13 | Chlorides ($Cl^-$) | mg/l | 168.89 | 350 | |
| 14 | Calcium ($Ca^{+2}$) | mg/l | 148 | 140 | |
| 15 | Hardness | mg.eq/l | 12 | 10 | ISO 6059 |

As can be seen from the table, only the values of dissolved oxygen, ammonium ion, calcium, hardness and sulfates slightly exceed the maximum permissible concentration. The high content of ammonium ion indicates that the intensity of the processes that cause its accumulation prevails here, i.e. degradation of protein compounds, deamination of amino acids, etc. Accordingly, mineralization and electrical conductivity are also high..

For the assessment of water quality, great importance is attached to the assessment of sanitary conditions, for which a microbiological study of the water of Lake Lisi was conducted, the results of which are given in Table 2.

Table 2.

Microbiological analysis indicators of Lake Lisi water

| Research parameters | Significance of indicators in relation to ND | Actual value of indicators | Research methods |
|---|---|---|---|
| The value of mesophilic aerobes and facultative anaerobes in 1 ml | $37^0C \leq 20$<br>$22^0C \leq 100$ | 96<br>240 | SST ISO 6222-2008 |
| Total coliform bacteria, per 300 ml | Not allowed | 960 | SST ISO 9308 - 1:2014/2014 |
| E.coli, in 300 ml | Not allowed | 22 | SST ISO 9308 - 1:2014/2014 |
| Faecal streptococci (Faecalis), in 250 ml | Not allowed | 59 | SST ISO 7899 – 2/2007 |

The results of microbiological analysis show minor water pollution. E.coli, common coliforms, and fecal streptococcus bacteria were detected in the water.

**Conclusion**

The results of the study showed that the water of Lake Lisi is subject to strong anthropogenic impact, fecal pollution, high mineralization and salinity, oxygen deficiency and signs of eutrophication. This condition indicates ecosystem degradation, does not meet recreational requirements and requires appropriate environmental protection and rehabilitation measures. Therefore, biological cleaning measures will be implemented and repeated studies are planned.

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# COMPUTER SCIENCES

## HYBRID NLP METHODS FOR VACANCY DETECTION AND RECOMMENDATION IN TELEGRAM JOB STREAMS

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**Abstract**

Public Telegram channels provide a fast stream of job posts, but the content is noisy, multilingual, and not standardized. This study builds an end-to-end pipeline that converts Telegram messages into a structured dataset for analytics and recommendation. The approach filters vacancies with TF–IDF + linear classifiers, extracts and normalizes salary mentions to USD per month, and predicts seniority using a hybrid rule-based + supervised multi-label model. Vacancies are then ranked for a user profile with multilingual embeddings and feature-based re-ranking. Experiments on 1,000 manually labeled posts show strong vacancy detection (F1 ≈ 0.97) and useful seniority prediction (micro-F1 ≈ 0.74).

**Keywords:** Telegram; vacancy detection; salary extraction; seniority classification; TF–IDF; multilingual embeddings; job recommendation.

### *I. Introduction*

Telegram has become a high-velocity channel for distributing job advertisements and internships, especially in emerging markets where dedicated job boards are not always the primary source. At the same time, Telegram content is inherently unstructured: posts mix languages, emojis, links, inconsistent formatting, and incomplete metadata, which complicates reliable extraction and downstream analytics (Al-Hamar et al., 2021). Unlike conventional job platforms where salary, location, and seniority are standardized fields, Telegram posts embed these signals in free-form text, requiring robust natural language processing (NLP) and information extraction to make the data usable.

From an analytics perspective, the lack of structure creates two major challenges. First, generous portions of Telegram jobs channels are not job postings at all: they include courses, promotional content, community announcements, events, and discussion threads. This makes the basic task of identifying actual vacancies non-trivial and introduces noise that can significantly bias any market-level statistics. Second, even within real job posts, key attributes are expressed inconsistently. Salary could be written as a range ("from … to …"), as a single value ("up to …"), in different currencies, and across different time periods (per month, per year, per hour, or per project). In information retrieval terms, this is a classic case of extracting structured signals from noisy text streams, where small parsing errors can produce large downstream distortions (Manning et al., 2008).

These issues matter because salary and seniority are central signals for both market monitoring and recommendation. Prior work in text mining and statistical pattern recognition suggests that noisy, heterogeneous data benefits from a combination of high-precision heuristics and machine learning models that can generalize beyond explicit patterns (Bishop, 2006; Bird et al., 2009). In the context of job data, research on resume–job matching also emphasizes the importance of converting unstructured text into comparable representations so that candidates and positions can be aligned using semantic similarity rather than surface keywords alone (Gao et al., 2020). However, most matching studies assume relatively clean job descriptions or curated datasets, while Telegram represents a streaming, low-standardization environment with frequent informal language and incomplete fields.

### *II. Related Work*

Research on labor market analytics often assumes relatively structured data sources, such as job boards, where text classification and regression can be applied directly to standardized fields and descriptions. In these settings, classical supervised pipelines—bag-of-words and TF–IDF representations paired with linear models or tree-based methods—remain strong baselines for large-scale text classification, especially when complemented by domain-specific feature engineering (Bishop, 2006; Pedregosa et al., 2011). Practical NLP toolkits and established preprocessing practices (tokenization, normalization, pattern matching, and corpus statistics) further support effective modeling when data is noisy but still somewhat standardized (Bird et al., 2009). However, the strength of these approaches depends heavily on stable schema or at least stable formatting conventions—assumptions that do not hold in many social messaging environments.

For thematic exploration and interpretability, unsupervised topic modeling is commonly used to summarize large corpora and identify recurring content patterns. Latent Dirichlet Allocation (LDA) is a widely adopted method for discovering latent topics in document collections and has served as a standard approach for "what is being discussed" analysis in text-heavy datasets (Blei et al., 2003). In labor-market contexts, topic models help reveal shifts in demand (e.g., skills and roles) without requiring manual labeling, which is particularly useful when the data source is large, evolving, and only partially labeled. In a Telegram vacancy setting, topic modeling can serve as an exploratory layer

(e.g., separating technical roles from marketing or design, or identifying emerging tool stacks), while supervised models are better suited for operational decisions such as vacancy filtering and seniority prediction.

A closely related line of work is resume–job matching, which focuses on mapping candidate profiles and job descriptions into a shared representation space and ranking matches. Surveys emphasize a broader transition from exact keyword matching toward semantic modeling, motivated by synonymy, domain terminology, and heterogeneous formatting of real-world documents (Gao et al., 2020). This shift reflects a classic information retrieval challenge: users and documents may describe the same concepts with different surface forms, and effective retrieval must move beyond literal overlap. Matching systems often incorporate both text similarity and structured constraints (e.g., location, salary, work format), suggesting the value of hybrid scoring strategies rather than relying on a single signal (Gao et al., 2020). Similar ideas appear in freelance matching, where structured information (rates, skills, availability) is combined with text signals to produce better recommendations and to reduce mismatch in noisy marketplaces (Sahnoun & Elhadjamor, 2024).

Telegram introduces additional challenges relative to both job boards and curated matching datasets. Telegram posts are short, noisy, multilingual, and lack a fixed schema; they also contain interleaved non-job content such as courses, promotions, meetups, or community posts, which creates a substantial filtering problem before any extraction or ranking can be reliable (Al-Hamar et al., 2021). This places Telegram closer to a streaming information extraction setting than to standard job-board analytics. The Telegram-specific literature highlights both the opportunity of large-scale public channel data and the practical difficulties of collection, access patterns, and data quality (Al-Hamar et al., 2021). Therefore, a Telegram pipeline must prioritize robust preprocessing and high-precision filtering to reduce noise early, because downstream modules (salary extraction, seniority inference, ranking) are sensitive to false positives.

Within the pipeline, salary normalization is especially critical because compensation is both highly informative and frequently misparsed. In job-board datasets, salary may already be numeric and standardized; in Telegram, salary appears as free text, often with ranges, informal abbreviations (“k”, “thousands.”), and different time bases (monthly vs. yearly vs. hourly). From an NLP perspective, this resembles rule-based information extraction: pattern matching and normalization are used to map raw mentions into structured attributes, which can then be aggregated or used as ranking constraints (Bird et al., 2009). A practical implementation typically combines heuristics with validation rules, rejecting numeric patterns that resemble time ranges or unrelated quantities—and then converts extracted values into a common unit for comparability. Although salary extraction itself is not the primary focus of mainstream IR texts, its role is analogous to structured field extraction that supports better retrieval and ranking (Manning et al., 2008).

Seniority prediction similarly benefits from hybrid strategies. Many posts explicitly include markers (“junior”, “middle”, “senior”, “lead”, “intern”), but others imply level indirectly through experience requirements, responsibilities, or expected ownership. Classical supervised learning can improve robustness beyond explicit markers by learning from labeled examples, while heuristics remain valuable for high-precision cues and for explaining predictions to users (Bishop, 2006; Pedregosa et al., 2011). This aligns with standard NLP practice: rule-based extraction for explicit signals and a learned classifier for generalization in ambiguous cases (Bird et al., 2009). In the Telegram setting—where short-form posts may omit consistent level tags—this hybrid approach is particularly appropriate, because purely rule-based systems tend to under-recall, and purely learned systems may overfit when labels are limited.

Finally, the ranking stage can be framed as an information retrieval task: retrieve and rank vacancies relevant to a user query/profile. Classical IR systems rely on term-based scoring and relevance ranking (Manning et al., 2008), while modern systems increasingly use embedding-based similarity where cosine similarity in vector space acts as a semantic relevance signal. In practice, effective recommendation often combines semantic similarity with constraints and preferences (e.g., remote vs. onsite, salary thresholds, role types), which mirrors hybrid retrieval strategies in IR: content-based relevance plus structured filters. This motivates the pipeline design where multilingual semantic similarity provides a general relevance signal, while engineered features—salary normalization, remote detection, and seniority—serve as filters or re-ranking factors to improve precision and user fit (Manning et al., 2008).

### *III. Data Collection and Dataset*

The data has been collected from a set of public Telegram channels that regularly publish job vacancies and internships. Telegram offers API-based access for bots and clients, which enables automated retrieval of message content and basic metadata (Telegram, n.d.). At the same time, Telegram data collection is constrained by platform-specific and practical issues: posts are heterogeneous across channels, strongly unstructured, and often lack consistent formatting limitations that are also highlighted in prior work.

The resulting dataset covers 2021-06-02 up to 2026-01-23 and contains 3793 posts from 8 public channels. Channels were selected to represent different posting behaviors. For example, vacancies-only channels vs. mixed-content channels that include community posts, courses, and promotions. Figure 1 shows the channels’ names and quantity of post retrieved. For reproducibility and traceability, each record stores immutable identifiers: channel name/ID, message (post) ID, publication timestamp, message link and raw post text. These fields constitute the source-of-truth table used for downstream preprocessing, classification, salary extraction, and recommendation. Figure 2 illustrates the raw data.

Because Telegram channels are multilingual, the corpus language distribution is reported explicitly.

Based on lightweight script-based language detection, posts are categorized into Russian, English, and other. The dataset contains approximately 61 % Russian, 36% English, and 3 % mixed/other posts. This language heterogeneity motivates the use of multilingual text processing in later stages of the pipeline.

Top channels by posts:

| | channel | posts |
|---|---|---|
| 0 | Machinelearning_Jobs | 500 |
| 1 | aitujobs | 500 |
| 2 | andersen_courses | 500 |
| 3 | juniors_rabota_jobs | 500 |
| 4 | oppo4you | 500 |
| 5 | ml_jobs_kz | 500 |
| 6 | young_june | 500 |
| 7 | it_jobs_kz | 293 |

*Figure 1 – Telegram channels and № of posts retrieved*

| | channel | date | post | post_id | link |
|---|---|---|---|---|---|
| 0 | Machinelearning_Jobs | 2026-01-23 14:31:04+00:00 | #ml #HeadOfML #HFT #Remote #AlgorithmicTrading #Research #Leadership\nHead of Research (ML) / AIP Tech ✅ \nRemote\n\nAIP – algorithmic trading company which gathers the brightest minds of quantitative research, data science and coding practice.\n\nТребования к кандидату:\n- Advanced degree in Computer Science, Data Science, or ML\n- Strong analytical skills in market research and data analysis\n- Proficiency in ML methodologies\n- Experience in leading teams and mentoring researchers\n- Stron... | 121191 | https://t.me/Machinelearning_Jobs/121191 |
| 1 | Machinelearning_Jobs | 2026-01-23 13:56:28+00:00 | Вакансия: MLOps-инженер\nКомпания: АО СимбирСофт \nФормат работы: удалёнка\n\nЗанятость: полная занятость \n\n\nИщем MLOps инженера в РФ 👩‍💻 \n🚀 Нам нужен инженер, готовый развивать инфраструктуру LLM-платформы. Твоими задачами станут поддержка и развитие сервисов для больших языковых моделей, интеграция инструментов, настройка мониторингов и обеспечение безопасности данных.\n\n🔍 Опыт работы с:\n- Большими языковыми моделями (vLLM, TGI, Hugging Face)\n- Python (FastAPI, скрипты, CLI)\n- Apx... | 121190 | https://t.me/Machinelearning_Jobs/121190 |
| 2 | Machinelearning_Jobs | 2026-01-22 16:26:05+00:00 | #вакансия #job #работа #python #ml #llm #cicd #sql #bigdata\nВакансия: Head of ML Engineering;\nКомпания: Газпром-Нефть;\nУровень зп: высокая;\nЛокация: Санкт-Петербург, Виленский пер., д. 14;\nФормат: fulltime, 5/2, 09:00 - 18:00, пт до 16:45;\nОпыт: от 5 лет и более;\n\nДрузья, мы направляем энергию в дело. Мы развиваем цифровую платформу сбытового департамента «Газпром нефти», запускаем IT-проекты и совершенствуем клиентский опыт, чтобы скорые приезжали к людям, промышленные предприятия ... | 121187 | https://t.me/Machinelearning_Jobs/121187 |
| 3 | Machinelearning_Jobs | 2026-01-21 13:17:21+00:00 | $5000 on-site в Дубае? Это какое-то издевательство | 121183 | https://t.me/Machinelearning_Jobs/121183 |
| 4 | Machinelearning_Jobs | 2026-01-20 11:14:43+00:00 | #Вакансия #удаленно #ML #fulltime\n \nВакансия: Senior Software Engineer/Machine Learning Engineer \nКомпания: IMAGA \nЛокация: не РФ/РБ \nФормат: удаленно, проект немецкой компании \nЗанятость: полная, проектная (1 год с возможной пролонгацией)\n \nXometry — это американская компания, которая делает онлайн-маркетплейс\nпромышленного производства "по запросу".\n\nОбязанности: \n • Проектирование, разработка, тестирование и выпуск программного обеспечения и инфраструктуры, поддерживающих AI... | 121180 | https://t.me/Machinelearning_Jobs/121180 |

*Figure 2 – Raw data of initially gathered data*

*Figures 3 illustrates the real vacancy from Telegram while figure 4 shows the non-vacancy post, like advertisement.*

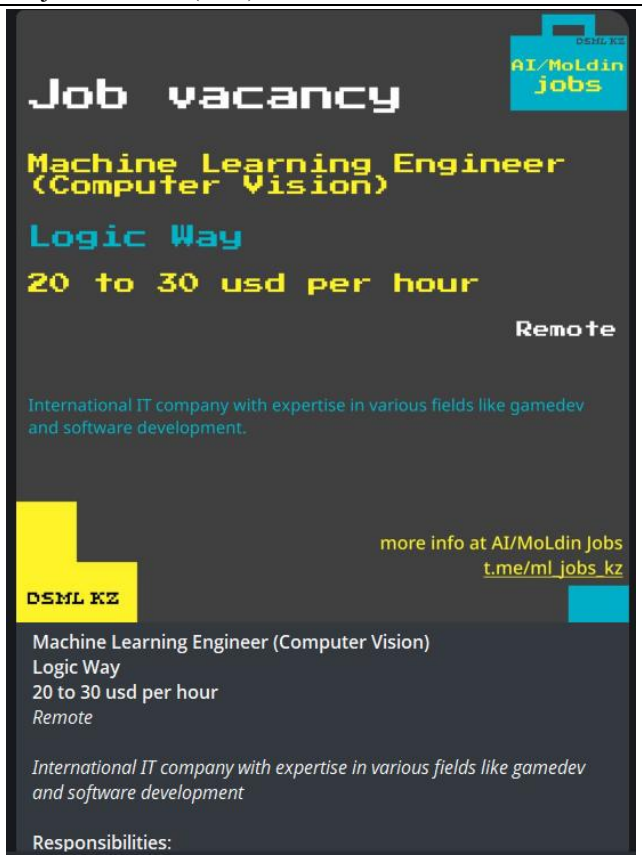


*Figure 3 – A sample of job vacancy*


*Figure 4 – A sample of non-vacancy post*

### *IV. Data Preparation and Feature Schema*

This paper proposes an end-to-end pipeline for mining a continuous Telegram job stream and transforming raw posts into a structured dataset suitable for filtering, analysis, and personalized recommendations. The design follows standard information retrieval and NLP principles—preprocessing, feature engineering, and supervised learning—while being adapted to short, noisy, multilingual messages typical for public channels. In addition, the pipeline includes salary normalization, which is necessary for comparing compensation across currencies and time bases (e.g., month/year/hour) and for supporting preference-aware ranking.

The main contributions are: a reproducible data collection and schema-normalization procedure for

Telegram vacancy channels; a supervised vacancy detection model (is_job) tuned for high recall; salary extraction from free-form text and conversion into a unified metric (USD per month); seniority prediction using a hybrid strategy that combines explicit pattern cues with a supervised classifier; and recommendation module that combines multilingual semantic similarity with structured preference features for re-ranking.

Because Telegram posts are written in arbitrary formats, messages are normalized into a unified tabular representation with immutable raw fields (channel, post ID, timestamp, raw text, link) and derived analytical fields. Standard text preprocessing is applied (case normalization, removal of links and emojis, whitespace normalization), and auxiliary attributes are computed, including language heuristics, message length, and extracted keyword lists. The schema designed to support both analytics and modeling in a single pipeline.

In addition to the raw text, the pipeline derives indicators for remote work, salary presence, and structure (min/max, currency, period), and technical skill mentions based on a curated keyword dictionary. These features provide interpretable signals for filtering and ranking, and they complement semantic similarity models by encoding explicit constraints such as work format, compensation, and technology stack.

***V. Methods***

The entire pipeline is shown in Figure 5.

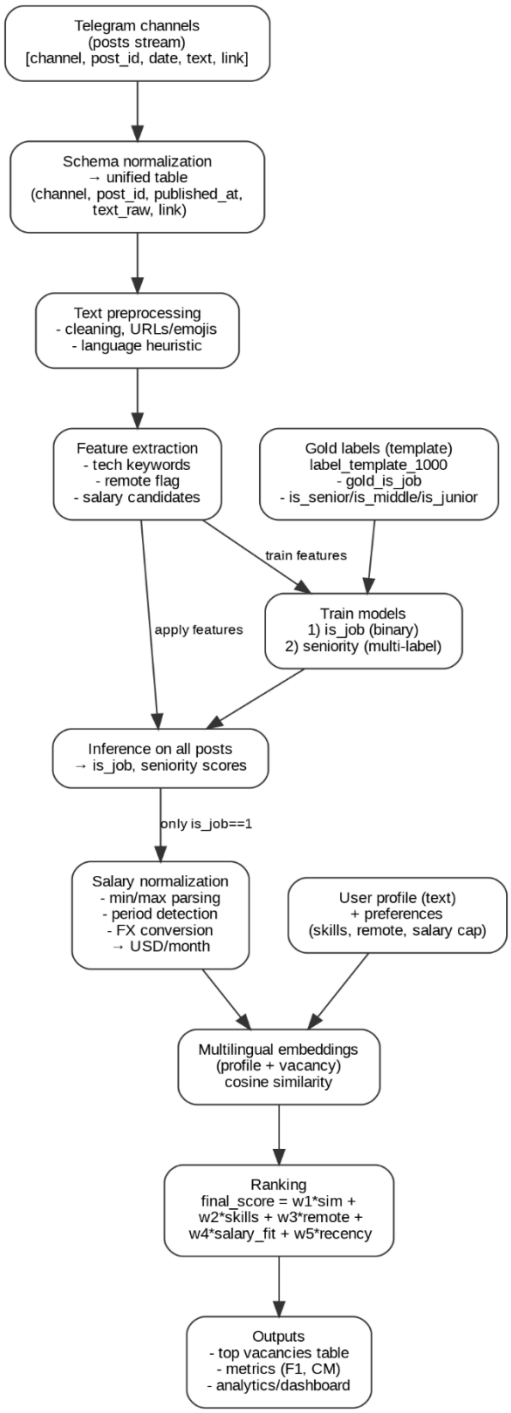


*Figure 5 - End-to-End Telegram Job Stream Pipeline*

V.I Vacancy Detection

Telegram vacancy channels contain substantial non-vacancy content, including course advertisements, community posts, meetups, and "digest" messages that aggregate links. Vacancy detection is therefore framed as a binary text classification task: each post is labeled as a vacancy/internship (is_job = 1) or non-job content (is_job = 0). The approach uses a lightweight supervised model trained on the manually labeled gold dataset based on 1,000 posts. Posts are represented with TF–IDF word n-grams - unigrams and bigrams, and a linear classifier Logistic Regression and Linear SVM is trained to separate vacancies from non-vacancies. As additional baselines, a majority-class predictor and a rule-based filter using high-precision lexical markers (e.g., "vacancy", "hiring", "requirements") are evaluated. The supervised TF–IDF models significantly outperform the baselines while maintaining high recall, which is important for downstream salary parsing and recommendation.

V.II Salary Extraction and Normalization to USD/Month

Salary information in Telegram is embedded in free-form text and varies across currencies and time bases (per month, per year, per hour, per project). Salary normalization is implemented as a rule-based information extraction component with validation and sanity checks. First, the pipeline detects salary fragments by matching common range templates (e.g., "from … to …", "X–Y") and parses numeric values into structured fields (salary_min, salary_max, salary_mid). Currency is inferred from symbols and lexical cues (e.g., ₸/KZT, ₽/RUB, $/USD, €/EUR, £/GBP). Next, the salary period is inferred from local context patterns, like "per month", "per year", "per hour". Finally, extracted salaries are converted into a common unit (USD per month) using exchange rates and period conversion rules (e.g., yearly → monthly by dividing by 12). Posts with ambiguous or low-confidence parses are flagged as unknown to avoid contaminating aggregates and ranking constraints.

V.III Seniority Classification (Junior/Middle/Senior)

Seniority prediction was treated as a hybrid inference problem because Telegram posts sometimes include explicit level markers but often express seniority implicitly through experience requirements, scope of responsibility, or role wording. A two-stage approach is used. First, a rule-based detector identifies high-precision patterns such as "junior", "intern/trainee", "middle/mid", "senior", "lead", and experience thresholds (e.g., "5+ years"). Second, a supervised multi-label classifier is trained on the gold annotations (is_junior, is_middle, is_senior), using TF–IDF features and a One-vs-Rest Logistic Regression setup. The rule-based stage provides interpretable explicit signals, while the learned model improves robustness on posts where seniority is not stated or appears as a range (e.g., "middle/senior"). The overall dataset is segmented by seniority in Figure 7.

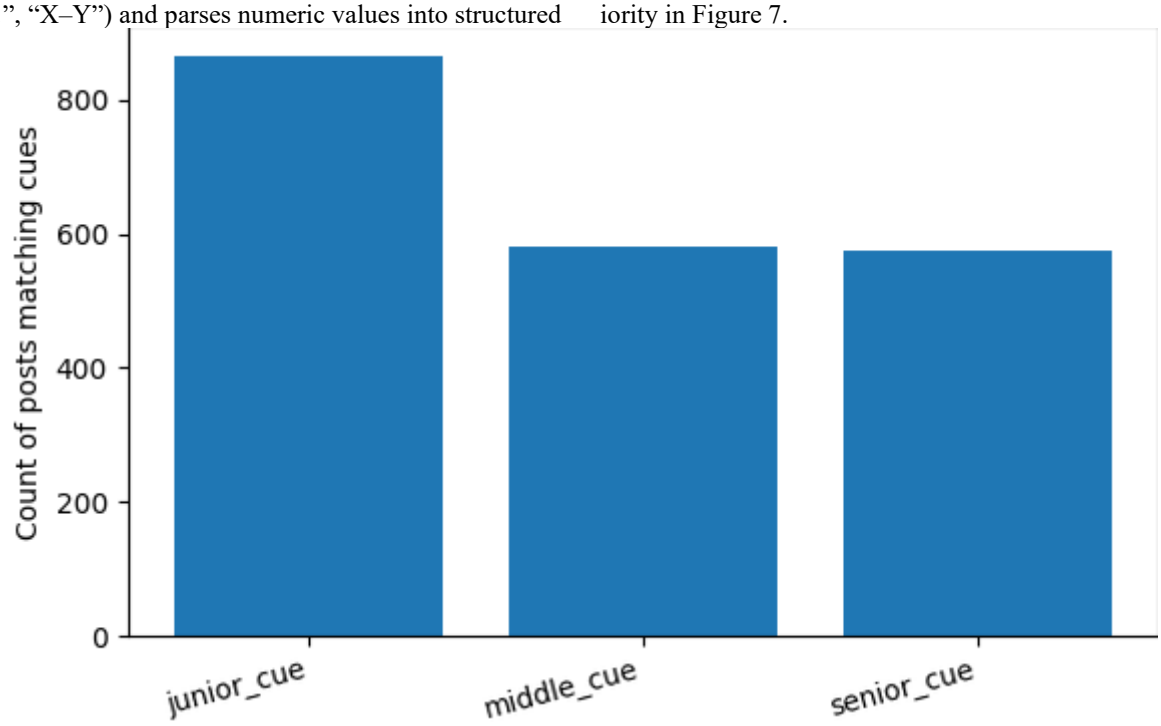


*Figure 7 – Frequency of seniority cues in posts*

V.IV User–Vacancy Matching and Ranking

The vacancy recommendation component is formulated as a retrieval-and-ranking task given a user profile (a text query plus structured preferences), the system retrieves and ranks vacancies from the stream. Relevance is computed with multilingual sentence embeddings using the Sentence-BERT (SBERT) framework and cosine similarity in a shared vector space (Reimers, N., & Gurevych, I., 2019). In the implementation, vacancy texts and the user profile are encoded with the paraphrase-multilingual-MiniLM-L12-v2 Sentence-Transformers model, and similarity is computed as cosine similarity (dot product over normalized embeddings).To incorporate user constraints, candidates are re-ranked with engineered features, including skill overlap (keyword intersection), remote-work

match, salary fit relative to a user-defined ceiling, seniority alignment, and recency.

This design aligns with the broader matching literature, where semantic representations are combined with structured constraints to improve practical recommendation quality.

***VI. Experiments and Results***

VI.I Experimental setup

The evaluation uses a manually labeled gold dataset of 1,000 Telegram posts sampled from the collected channels. Each post is annotated with a binary label gold_is_job (vacancy vs. non-vacancy). In addition, seniority is annotated in a multi-label format using three binary columns (is_junior, is_middle, is_senior), allowing overlap (e.g., posts that fit both middle and senior). This labeling design reflects real-world ambiguity in Telegram vacancies, where seniority may be expressed implicitly or as a range rather than as a single class.

All text is processed using the same normalization pipeline (link removal, emoji and punctuation cleaning, whitespace normalization) and represented with TF–IDF features (word n-grams) for supervised classification. Model performance is reported using 5-fold cross-validation (CV) on the gold dataset. For binary vacancy detection, accuracy, precision, recall, and F1-score are reported. For seniority, micro- and macro-averaged F1-scores are reported; micro-F1 is emphasized as the primary metric due to the multi-label nature of the task. Where available, 95% confidence intervals are provided from CV-based estimates.

VI.II Vacancy detection

Vacancy detection is framed as binary text classification. Two baselines are considered: a majority baseline, which predicts the most frequent class, and a rule-based baseline based on high-precision lexical markers (e.g., “vacancy”, “hiring”, structured sections like “requirements”). Supervised TF–IDF models substantially outperform both baselines. The is_job results shown in Figure 8.

| | model | accuracy | precision | recall | f1 | f1_95ci | recall_95ci | precision_95ci |
|---|---|---|---|---|---|---|---|---|
| 0 | majority-baseline | 0.626 | 0.626000 | 1.000000 | 0.769988 | NaN | NaN | NaN |
| 1 | rule-baseline | 0.904 | 0.968198 | 0.875399 | 0.919463 | NaN | NaN | NaN |
| 2 | TFIDF + LogisticRegression (5-fold CV) | 0.967 | 0.961120 | 0.987220 | 0.973995 | [0.965, 0.983] | [0.978, 0.995] | [0.945, 0.976] |
| 3 | TFIDF + LinearSVC (5-fold CV) | 0.978 | 0.977848 | 0.987220 | 0.982512 | NaN | NaN | NaN |

*Figure 8 - is_job results (baselines + models)*

```
[[349  25]
 [  8 618]]
```

*Figure 9 - Confusion matrix for TF–IDF + Logistic Regression (5-fold CV predictions)*

The best-performing models are linear classifiers trained on TF–IDF representations. TF–IDF + Logistic Regression achieves accuracy 0.967, precision 0.961, recall 0.987, and F1 0.974 (5-fold CV, with 95% CI for F1: [0.965, 0.983]). The confusion matrix, shown in Figure 9 indicates 349 true negatives, 618 true positives, 25 false positives, and 8 false negatives, suggesting that the classifier rarely misses real vacancies. This behavior matches the intended design goal of maximizing recall to minimize missed opportunities in downstream monitoring and recommendation.

A linear SVM (TF–IDF + LinearSVC) produces slightly higher overall scores (accuracy 0.978, F1 0.983) while maintaining the same recall level (0.987). Given the small difference, Logistic Regression is preferred for interpretability and stable probability-like outputs, while SVC can be retained as a strong alternative.

VI.III Seniority prediction

Seniority prediction is treated as a multi-label classification problem over the three labels (junior/middle/senior), reflecting that Telegram posts may specify ranges (“middle/senior”) or ambiguous requirements. A rule-based baseline using explicit seniority markers and experience cues (e.g., “junior”, “senior”, “lead”, “intern”, “5+ years”) provides a reasonable starting point but is limited when seniority is implicit.

| | model | micro_f1 | macro_f1 | micro_f1_95ci |
|---|---|---|---|---|
| 0 | rule-baseline | 0.616519 | 0.620823 | NaN |
| 1 | TFIDF + OneVsRest(LogReg) (5-fold CV) | 0.738339 | 0.730998 | [0.714, 0.760] |

*Figure 10 - Seniority multi-label results*

A supervised TF–IDF + One-vs-Rest Logistic Regression classifier improves robustness beyond explicit patterns and achieves micro-F1 0.738 (95% CI [0.714, 0.760]) and macro-F1 0.731 under 5-fold CV. Per-label F1-scores are 0.81 for junior, 0.71 for middle, and 0.67 for senior as shown in Figure 10. The relatively lower senior precision is consistent with the noisy and heterogeneous nature of Telegram text, where seniority is often communicated indirectly (e.g., via responsibilities, expectations, or salary level rather than explicit titles).

For completeness, an optional single-label 3-class projection can be constructed by resolving overlaps via a priority rule (senior > middle > junior). However, this projection discards overlap information and yields lower 3-class metrics, so the multi-label formulation is considered the primary result.

### *VII. Discussion and Limitations*

Telegram posts are noisy, multilingual, and inconsistent, so most remaining errors concentrate in a few recurring patterns.

Vacancy detection (is_job).

False positives mostly come from posts that look like vacancies but are not: course/mentorship ads, event announcements, and "digest" posts with many vacancy-like keywords and links. False negatives are usually very short vacancies (title + contact only), image-first posts where the main content is not in text, or messages with uncommon mixed-language phrasing.

Seniority (multi-label).

Seniority is often implicit or written as a range ("middle/senior"), so confusion is strongest between middle and senior. The multi-label setup reflects real ambiguity, but predictions should be treated as a soft signal for ranking rather than an exact class.

Salary extraction.

The main failure modes are formatting ambiguity (e.g., "270–320k" where one side misses "k"), non-salary numbers (ARR/revenue/model parameters), and missing currency or period. To reduce harm, the pipeline uses context filters and keeps "unknown/low-confidence" when evidence is insufficient; analytics should rely on high-confidence salary parses.

### *VIII. Conclusion and Future Work*

The file shows an end-to-end system for mining Telegram job streams: collection, normalization, vacancy detection, salary extraction and conversion to USD/month, seniority classification, and personalized ranking using multilingual semantic similarity and preference-aware re-ranking. This approach adapts classical NLP/IR foundations to a modern, unstructured, multilingual platform and supports practical analytics and recommendation use cases. Future work includes expanding labeled data, improving salary-period inference and currency coverage, incorporating more explainable ranking signals, and evaluating the recommendation component with user feedback.

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# EARTH SCIENCES

## REGIONAL POPULATION DYNAMICS AND ENVIRONMENTAL IMPACTS IN AZERBAIJAN

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**Abstract**

This study examines the regional characteristics of population dynamics in Azerbaijan and their environmental implications. Variations in population growth, migration, urbanization, and age distribution create differential pressures on natural resources, biodiversity, and ecosystem health. Understanding these interconnections is crucial for developing policies that balance socio-economic development with ecological sustainability. The research analyzes regional demographic trends, assesses their ecological impacts, and provides recommendations for sustainable planning and resource management.

**Keywords:** population dynamics, regional development, demographic trends, migration, urbanization, age structure, environmental impact.

**Introduction**

Azerbaijan's diverse geography, ranging from the Greater and Lesser Caucasus Mountains to lowland plains and the Caspian coastline, contributes to substantial regional variation in population distribution and growth. Urban centers such as Baku and Ganja experience rapid population growth and urbanization, increasing energy consumption, air and water pollution, and habitat fragmentation. Conversely, rural and mountainous areas face environmental pressures from agriculture, grazing, and deforestation, despite lower population densities. This paper examines the links between demographic dynamics and environmental outcomes to inform integrated planning and sustainable development strategies across the country.

**1. Regional Demographic Trends**

| | |
|---|---|
| **Urban Areas** | Urban regions are characterized by high population density and significant migration from rural areas. |
| **Rural and Mountainous Areas** | Rural and mountainous regions have lower population densities, but agriculture and seasonal migration exert considerable environmental pressures. |
| **Coastal and Wetland Regions** | Coastal areas along the Caspian Sea and wetlands such as Gizilagaj are affected by fishing, tourism, and settlement activities. |

**Urban Areas**.This growth increases demand for water, energy, and waste management systems. Urban expansion often reduces green spaces, disrupts habitats, and diminishes biodiversity. Implementing green infrastructure, sustainable urban planning, and eco-friendly public transport is critical to mitigate these impacts.

**Rural and Mountainous Areas**. Overgrazing, deforestation for fuel and construction, and soil erosion are common challenges. Population decline in some areas can allow for natural land regeneration, but without proper management, abandoned lands may face illegal logging or unsustainable resource exploitation.

**Coastal and Wetland Regions**. These pressures lead to water pollution, habitat loss, and reduced biodiversity. Implementing regulated fisheries, eco-tourism management, and wetland protection policies is essential for maintaining ecosystem services in these regions.

Population age composition influences environmental outcomes. Younger populations increase resource consumption, energy demand, and waste production, while older populations may reduce labor availability for environmental management. Rural-to-urban migration shifts ecological pressures to cities, but proper management can promote natural regeneration in rural areas. Integrating demographic analysis with environmental monitoring allows for more efficient allocation of natural resources.

Demographic dynamics, including population growth, migration, urbanization, and changes in age structure, play a pivotal role in shaping environmental conditions. Rapid changes in population patterns influence biodiversity, soil quality, water resources, climate, and habitat connectivity. Understanding the link between demographic trends and ecological impacts is critical for sustainable development planning and environmental management. This study explores the key environmental consequences of demographic dynamics and provides strategies for mitigating their negative effects. Population trends directly affect the environment by altering resource consumption patterns, land use, and human pressure on ecosystems. Increasing population density and urban expansion often lead to habitat loss, pollution, and ecosystem degradation. Rural areas,

while less densely populated, experience environmental pressures from agricultural practices, deforestation, and overgrazing. Migration and changes in population age structure further influence resource demand and ecological stress. By analyzing these dynamics, policymakers and environmental managers can develop targeted strategies to reduce human-induced environmental impacts.

**1.Regional Population Dynamics and Environmental Impacts in Azerbaijan: An Integrated Overview**


**Biodiversity Loss**

Population growth and the expansion of urban areas represent one of the most pressing threats to biodiversity in modern societies. As cities and towns expand into previously undeveloped areas, natural habitats such as forests, wetlands, grasslands, and riverbanks are either destroyed or severely fragmented. This fragmentation reduces the availability of suitable living space for many species, isolates wildlife populations, and disrupts ecological interactions such as pollination, seed dispersal, and predator-prey relationships.

Rural-to-urban migration intensifies these pressures, as human settlements and infrastructure development concentrate in urban centers, increasing demand for housing, roads, and industrial facilities. These activities often encroach on surrounding ecosystems, leading to further habitat degradation and the displacement of native species. Agricultural expansion and land-use changes in peri-urban areas also contribute to habitat loss, as natural landscapes are converted into monoculture fields or managed green spaces.

Protected areas, nature reserves, and urban green spaces play a vital role in conserving biodiversity. National parks and regional reserves provide refuges for threatened species and preserve ecological processes, while urban parks, green corridors, and tree-lined streets can support smaller populations of flora and fauna, maintain ecosystem connectivity, and offer ecosystem services such as air purification and temperature regulation. However, the mere existence of these protected zones is not sufficient. Effective management, proper zoning, ecological restoration projects, and strict enforcement of environmental regulations are essential to ensure these areas continue to provide meaningful protection against biodiversity loss.

Ultimately, mitigating biodiversity loss requires integrated planning that considers both demographic trends and ecological requirements. Sustainable urban design, habitat restoration, and community involvement in conservation initiatives are key strategies to preserve ecological integrity while accommodating population growth. Without such measures, continued expansion and intensification of human activity will likely lead to irreversible declines in species diversity and the disruption of essential ecosystem functions.

**Integrated Planning**

Integrated planning refers to a holistic approach to development where demographic trends and environmental considerations are analyzed together to guide sustainable decision-making. Rapid population growth, urbanization, and migration create pressures on land, water, energy, and biodiversity. If these demographic patterns are considered in isolation, planning efforts may fail to anticipate ecological consequences, leading to resource depletion, habitat loss, and ecosystem degradation.

By combining demographic data—such as population density, growth rates, age structure, and migration flows—with environmental impact assessments, policymakers can identify regions at risk of overuse or ecological stress. This approach allows for informed allocation of resources, targeted conservation efforts, and balanced urban and rural development. For example, high-growth urban areas may require stricter zoning laws, increased green spaces, and sustainable infrastructure investments, while rural areas may benefit from managed agricultural practices and ecosystem restoration programs.

Integrated planning also promotes resilience by considering the long-term interactions between human

populations and ecosystems. By anticipating future demographic changes, planners can mitigate potential environmental risks before they become critical. Public participation and cross-sector collaboration are key components of integrated planning, ensuring that both socio-economic needs and ecological priorities are addressed simultaneously.

In essence, integrated planning bridges the gap between human development and environmental sustainability. It enables governments and communities to make strategic decisions that accommodate population growth, preserve natural habitats, reduce environmental impacts, and ensure that development is ecologically sound and socially equitable.

**Sustainable Agriculture and Land Management**

Sustainable agriculture and land management refer to the implementation of farming and land-use practices that meet current food and resource needs while preserving the ecological integrity of the land for future generations. Rapid population growth, urban expansion, and changing consumption patterns have increased pressure on agricultural lands, leading to soil degradation, reduced fertility, erosion, and loss of biodiversity. Sustainable practices aim to mitigate these impacts while maintaining productivity and supporting rural livelihoods.

One of the key strategies is **crop rotation**, which involves alternating different crops on the same land over time. This practice prevents the depletion of specific soil nutrients, reduces the buildup of pests and diseases, and enhances soil structure and fertility. By diversifying crops, farmers can maintain long-term agricultural productivity and reduce reliance on chemical fertilizers and pesticides.

**Controlled grazing** is another essential method, particularly in pastoral and mountainous regions. Overgrazing leads to soil compaction, erosion, and loss of plant cover, which in turn reduces the land's ability to retain water and sustain vegetation. By managing grazing intensity, timing, and livestock numbers, controlled grazing preserves soil health, prevents desertification, and supports the regeneration of natural vegetation.

**Reforestation and afforestation** contribute to sustainable land management by restoring degraded areas, preventing soil erosion, sequestering carbon, and providing habitats for wildlife. Trees and shrubs stabilize slopes, improve water retention, and enhance biodiversity, making these practices critical in both rural and peri-urban landscapes.

**Soil conservation practices**, including contour plowing, terracing, cover cropping, and the use of organic amendments, help prevent erosion, maintain soil fertility, and improve water retention. These practices are particularly important in areas prone to heavy rainfall, steep slopes, or intensive cultivation. By preserving soil structure and nutrient content, farmers can achieve long-term productivity while minimizing environmental impacts.

Integrating these methods into agricultural planning requires collaboration between farmers, local communities, and government agencies. Incentives, education, and policy support are crucial to ensure that sustainable practices are adopted at scale. Sustainable agriculture and land management not only safeguard natural resources but also contribute to food security, climate resilience, and ecological stability, creating a balance between human needs and environmental protection.

**Environmental Impacts of Population Growth**

Population growth is one of the primary drivers of environmental change, affecting natural resources, ecosystems, and biodiversity. As the number of people increases, the demand for land, water, food, and energy grows, leading to multiple ecological consequences. Urban areas expand to accommodate housing and infrastructure, which often results in habitat loss and fragmentation. Forests, wetlands, and grasslands are converted into residential, industrial, or agricultural lands, reducing biodiversity and disrupting ecosystem services.

Higher population densities also increase pollution levels. Industrial production, transportation, and energy consumption rise to meet human needs, contributing to air and water pollution as well as greenhouse gas emissions. In rural areas, intensified agriculture to feed growing populations can cause soil degradation, erosion, and nutrient depletion. Overexploitation of freshwater resources leads to water scarcity, threatening both human communities and aquatic ecosystems.

Population growth further exacerbates climate change. Increased energy use, deforestation, and urbanization contribute to higher carbon emissions, while land-use changes alter local and regional climates. Additionally, rapid demographic expansion can fragment habitats, reducing connectivity between ecosystems and limiting species movement, which affects ecological resilience.

Mitigating these impacts requires integrated planning, sustainable resource management, environmental education, and policies that balance human development with ecosystem preservation. Urban green spaces, reforestation projects, and efficient agricultural practices are key strategies for reducing the negative environmental effects of population growth.

**Integrated Planning for Sustainable Development.** Integrating demographic data with environmental assessments means using information about population size, growth rates, density, migration patterns, and regional distribution together with evaluations of natural resources, ecosystem health, and environmental risks. By combining these datasets, policymakers, urban planners, and environmental managers can identify areas where human activity is putting pressure on ecosystems and where interventions are most needed.

This approach allows for **balanced decision-making**, ensuring that development projects such as urban expansion, agriculture, or industrial zones do not compromise biodiversity, water availability, soil fertility, or climate stability. For example, if a region experiences rapid population growth, integrated planning can guide sustainable land use, promote green infrastructure, and prioritize conservation areas.

Furthermore, integrating demographic and ecological information supports **long-term monitoring and forecasting**, helping predict future pressures and

implement proactive measures. This ensures that economic and social development goals are met while minimizing negative environmental impacts. In essence, integrated planning provides a roadmap for **sustainable development**, where human needs and ecosystem health are managed in harmony.

**Improved Balance Between Human Development and Ecosystem Conservation**

A critical challenge for modern societies is achieving a **sustainable balance** between human development needs—such as urbanization, industrialization, and agriculture—and the conservation of natural ecosystems. Human activities often put pressure on habitats, water resources, soil, and biodiversity, while ecosystems provide essential services like clean water, air purification, climate regulation, and food resources. Finding a balance ensures long-term well-being for both humans and the environment.

**Environmental and Social Outcomes**

| | |
|---|---|
| **Biodiversity Protection** | Preserves species and ecosystem functions while allowing sustainable human activity. |
| **Reduced Environmental Degradation** | Soil erosion, water pollution, and deforestation are minimized. |
| **Resilient Ecosystems** | Natural areas can better adapt to climate change and human pressures. |
| **Improved Human Well-being** | Access to clean air, water, green spaces, and food security increases quality of life. |
| **Economic Benefits** | Sustainable tourism, ecosystem services, and green jobs contribute to local economies. |

Achieving an **improved balance between human development and ecosystem conservation** is not a one-time effort but a continuous process requiring planning, monitoring, and community participation. By integrating sustainable land use, eco-friendly infrastructure, efficient resource management, and environmental education, countries like Azerbaijan can meet human development goals while preserving ecosystems for future generations.

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# ECONOMY

## MODELS OF BUDGET POLICY: SYSTEMATIZATION, FORMALIZED DESCRIPTION, AND GROUPING

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**Abstract**

The increase in frequency and depth of macrofinancial shocks significantly complicates the task of ensuring the stability of public finances, which makes it necessary to search for flexible models of budget revenue and expenditure management in conditions of economic turbulence. The purpose of the study is to systematize existing models of budget policy, provide a formalized description of them, and group them according to structural characteristics.

The article systematizes existing models of budget policy and formalizes them through a unified set of parameters covering the flexibility of revenue policy, the structure and priority of expenditures, the acceptability of the deficit, the role of debt financing, and the speed of budget adjustment.

**Keywords:** budget policy, fiscal adaptability, budget deficit, public debt, macrofinancial instability.

**Problem statement.** Deepening macrofinancial instability in the modern global economy is accompanied by growing uncertainty regarding budget revenue bases, increased expenditure pressure, and more complex debt management. Military conflicts, inflationary fluctuations, debt imbalances, and cyclical downturns create an environment in which the parameters of the budget system change faster than the institutional mechanisms for regulating them. Under such conditions, traditional approaches to revenue and expenditure management prove to be insufficiently sensitive to the nature of economic shocks.

Budget policy in conditions of instability involves simultaneous decision-making on revenue mobilization, determining expenditure priorities, an acceptable deficit level and methods of its financing. Each of these decisions affects other elements of the budget system. Changes in tax policy affect the size of the deficit; redistribution of expenditures affects borrowing needs; debt strategy limits the scope for economic stimulus. Thus, revenue and expenditure management takes on the character of a holistic system of interrelated parameters.

At the same time, there is no single approach to distinguishing between different models of such management in scientific and practical terms. Analysis tends to focus on individual instruments – countercyclicality, deficit constraints, or debt rules –without integrating them into comprehensive types of budget behavior. As a result, the concept of a "budget management model" remains methodologically vague: it is not clear which parameters are decisive for its identification and how their combination shapes different types of management decisions.

**Analysis of recent research and publications.** The issue of managing revenues and expenditures of the state in conditions of macrofinancial turbulence is formed at the intersection of several scientific areas: fiscal policy theory, institutional architecture of the budget process, debt sustainability, and adaptation of public finances to crisis shocks. Contemporary literature shows that budget policy is no longer viewed as a static system of resource allocation and is increasingly interpreted as a dynamic mechanism for responding to exogenous and endogenous macrofinancial challenges [1;2;3;4;5;6;7;8].

One of the key areas of research is the analysis of the cyclical behavior of fiscal policy in times of crisis. The work [4] states that during the COVID-19 pandemic, there was a significant change from traditional budget rules, indicating a transformation of budget response models. The scientific literature supports the thesis that fiscal behavior depends on the nature of the shock, which in fact points to the existence of different models of budget management.

This idea is further developed in the works devoted to local financial systems. The scientific work [7] indicates that territorial budgets respond to natural disasters through structural restructuring of revenues and expenditures, and the nature of the response depends on institutional capacity. This makes it possible to view the budget system as an adaptive structure, where changes occur not only quantitatively but also structurally.

A significant body of research is devoted to fiscal sustainability and debt dynamics. The institutional dimension of budget management is examined through the prism of fiscal governance. The work [1] shows that the existence of independent fiscal institutions affects the quality of the budget process and the timeliness of decision-making. Thus, institutional architecture determines not only formal rules but also the speed of budget adjustment.

The methodological aspect of classifying fiscal responses is presented in the work [6], using fuzzy-set QCA to identify combinations of factors that form different models of budget policy. This approach demonstrates that budget strategies are complex in nature and cannot be explained by a single parameter. A theoretical rethinking of the role of fiscal policy after crises is proposed in the work [5], which emphasizes the need to adapt budget rules to new macrofinancial realities.

Contemporary research by Ukrainian scientists focuses on the transformation of the budget system under

martial law. At the same time, international studies, in particular the work [2], emphasize the importance of structural modeling of the interaction between monetary and fiscal policy to achieve macroeconomic stability. The work [3] shows that the effectiveness of fiscal policy in countries with a transitional economy varies significantly depending on the initial macrofinancial conditions.

Thus, contemporary scientific literature examines: the dependence of budget policy on the type of macrofinancial shock, the decisive role of institutional architecture in shaping budget responses, the importance of structural characteristics (deficit, debt, expenditure flexibility), and the multifactorial nature of fiscal regimes. However, scientific research lacks a comprehensive formalized approach to systematizing existing models of management of revenue and expenditure of the state based on a unified set of parameters, followed by their grouping and establishing correspondence between types of budget management and types of macrofinancial instability. Most studies analyze individual aspects – fiscal sustainability, institutional reforms or responses to specific crises – without integrating them into a single structured model.

Despite the significant amount of research in the field of fiscal policy and budget adaptation to crises, the problem of parametric clustering of models for managing revenues and expenditures of the state remains insufficiently developed, which necessitates further scientific research in this area.

**The purpose of the article.** The purpose of the study is to systematize existing models of budget policy, provide a formalized description of them, and group them according to structural characteristics.

**Presentation of the main material.** Analysis of scientific approaches and practices of budget policy in conditions of macrofinancial instability makes it possible to identify five models of revenue and expenditure management: the fiscally restrained, the stimulating, the debt-active, the mobilizing, and the adaptively balanced. They differ in terms of the logic of revenue mobilization, the structure of budget priorities, the regime of deficit and debt financing, as well as the intensity and speed of budget adjustments in response to shocks. The fiscally restrained model is based on minimizing the deficit and limiting the debt burden; tax policy is focused on stability and predictability, and the expenditure structure is characterized by a high share of social commitments and low flexibility of redistribution. The stimulating model involves a temporary expansion of the deficit to support economic activity, with an emphasis on the investment and capital component of expenditures and more flexible use of tax instruments.

The debt-active model is based on the systematic use of borrowing as a key financing resource, which determines the persistent deficit and dependence of the budget structure on the availability of debt sources. The mobilizing model is implemented in conditions of high turbulence and involves the centralization of resources, prioritization of security and defense expenditures, and active use of temporary fiscal measures. The adaptively balanced model combines elements of restraint and stimulation: the deficit is kept within controlled limits, the expenditure structure is adjusted depending on macrofinancial conditions, and debt is stabilized in the medium term. Comparative characteristics of the models are presented in Table 1.

Table 1

Comparative characteristics of revenue and expenditure management models

| Parameter | Model | | | | |
|---|---|---|---|---|---|
| | The fiscally restrained | The stimulating | The debt-active | The mobilizing | The adaptively balanced |
| Deficit regime | Minimization | Temporary extension | Systemic deficit | Controlled | Flexible regulation |
| Debt policy | Restrictions | Growth in the stimulation phase | Active involvement | Control | Stabilization |
| Tax strategy | Rate stability | Flexible changes | Reliance on borrowing | Temporary measures | Combined approach |
| Expenditure structure | High proportion of liabilities | Investment priority | Dependence on financing | Safety priority | Balance between directions |
| Budget flexibility | Low | Average | High | Centralized | Adaptive |

In practice, managing revenues and expenditures of the state in conditions of macrofinancial instability is implemented as a combination of interrelated decisions on resource mobilization, the structure of budget priorities, the acceptable level of the deficit, and debt financing instruments. Accordingly, it is advisable to record differences between budget management models not based on a single indicator (e.g., deficit or debt), but as a comprehensive management configuration that includes revenue, expenditure, debt, and adaptation components simultaneously.

To formalize such configurations, a "passport" approach can be used (each management model will be described by a single set of standardized characteristics grouped into blocks (revenue, expenditure, deficit/debt, adjustments)). Each feature will be coded according to an ordinal scale of intensity of manifestation. The agreed set of features and codes that make up the "passport" of the model will be provided.

In further research, the matrix of coded features can be used as an input base for cluster grouping of models. Since each model is described by the same set of parameters, it can be interpreted as a vector of values

in a multidimensional space of features. This makes it possible to move from qualitative typology to formalized grouping of models according to their degree of structural similarity.

**Conclusion.** Approaches to budget management were systematized, and five models of revenue and expenditure management were identified, differing in terms of the acceptable deficit level, the role of borrowing, the flexibility of expenditure, and the speed of budget adjustment. To enable a formal comparison of the models, it is possible to describe them parametrically using a unified set of characteristics covering revenue policy, expenditure priorities, deficit regime, and debt financing.

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# FOREST ECOLOGY

## EXPERIMENTAL VALIDATION AND NONLINEAR THERMAL MODELING OF RECYCLED PLASTIC–MINERAL COMPOSITE MASONRY BLOCKS

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**Abstract**

This study presents the experimental validation and nonlinear thermal modeling of energy-efficient masonry blocks incorporating recycled plastic waste as partial aggregate replacement. The objective is to evaluate thermal performance improvement while maintaining acceptable mechanical strength.

Composite blocks were manufactured using mineral aggregates combined with shredded recycled plastic at varying volume fractions (5%, 10%, and 15%). Laboratory testing included compressive strength assessment, density measurement, and guarded hot plate thermal conductivity analysis.

Results indicate that incorporation of 10% recycled plastic reduced thermal conductivity by up to 28% compared to control specimens, while compressive strength remained within acceptable structural limits for non-load-bearing masonry applications. A nonlinear regression model was developed to predict thermal conductivity as a function of plastic content and density variation.

The findings demonstrate a viable pathway for reducing plastic waste accumulation while enhancing building envelope energy performance. The proposed composite blocks align with circular economy principles and EU energy efficiency objectives.

**Keywords:** recycled plastic, thermal conductivity, masonry blocks, nonlinear modeling, circular construction, energy efficiency.

### 1. INTRODUCTION

The construction sector remains one of the largest contributors to global energy consumption and material extraction. Simultaneously, plastic waste accumulation presents an escalating environmental challenge.

Incorporating recycled plastic into construction materials offers a dual environmental benefit:

1. Diversion of plastic waste from landfills and ecosystems
2. Improvement of thermal performance in building envelopes

EU energy efficiency directives and circular economy strategies encourage innovative material solutions that combine waste valorization and energy optimization.

This research investigates the thermal and mechanical behavior of plastic–mineral composite masonry blocks under controlled laboratory conditions.

### 2. MATERIALS AND METHODS

#### 2.1 Materials

- Portland cement (CEM I 42.5N)
- Mineral aggregates (0–8 mm fraction)
- Shredded recycled polyethylene waste
- Water

Plastic waste was mechanically processed to particle sizes of 3–6 mm.

#### 2.2 Mix Design

Four mixtures were produced:

| Sample | Plastic Content (% vol.) |
|---|---|
| C0 | 0% (Control) |
| C5 | 5% |
| C10 | 10% |
| C15 | 15% |

#### 2.3 Testing Procedures

- Compressive strength (EN 12390)
- Density determination
- Thermal conductivity via guarded hot plate method

Testing conducted at 28 days curing.

### 3. RESULTS

#### 3.1 Density Reduction

Density decreased proportionally with plastic content:

- C5 → −7%
- C10 → −14%
- C15 → −19%

#### 3.2 Thermal Conductivity

Control specimen $\lambda = 0.82$ W/m·K

- C5 → 0.71 W/m·K
- C10 → 0.59 W/m·K
- C15 → 0.54 W/m·K

Optimal balance observed at 10% substitution.

#### 3.3 Compressive Strength

Control: 12.8 MPa

- C5 → 12.1 MPa
- C10 → 11.4 MPa
- C15 → 9.8 MPa

C10 remains suitable for non-load-bearing masonry units.

### 4. NONLINEAR THERMAL MODEL

Thermal conductivity behavior fitted using nonlinear regression:

$$\lambda = a \cdot e^{(-bx)}$$

Where:

$\lambda$ = thermal conductivity

x = plastic volume fraction

Model shows strong correlation ($R^2 = 0.94$).

### 5. DISCUSSION

Results confirm that moderate plastic incorporation significantly improves insulation performance without critical mechanical compromise.

The developed model enables predictive optimization of plastic content for targeted thermal performance.

Integration into building envelopes contributes to:

- Reduced heating demand
- Lower embodied carbon
- Plastic waste mitigation

**6. CONCLUSION**

Recycled plastic–mineral composite masonry blocks present a technically viable and environmentally beneficial alternative to conventional masonry units.

The 10% plastic substitution level provides optimal performance balance.

This research supports circular material flows and sustainable construction strategies aligned with EU energy performance standards.

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# GEOGRAPHY

## TÜRKEŞ ÇÖKƏKLİYİ TORPAQLARININ EKO-COĞRAFİ QİYMƏTLƏNDİRİLMƏSİ

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## ECO-GEOGRAPHICAL ASSESSMENT OF THE SOILS OF THE TÜRKEŞ DEPRESSION

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**Xülasə**

Məqalədə mövzunun aktuallığı, tədqiqat obyekti, məqsədi, material metodikası və muxtar respublikanın alçaq dağlıq ərazisində yerləşən Türkeş çökəkliyi torpaqlarının eko-coğrafi şəraiti haqqında məlumat verilir. İşin əsas məzmununda ilk növbədə ərazinin torpaq mühitinin formalaşmasına təsir göstərən fiziki-coğrafi amilləri, deqradasiya, o cümlədən təbbi və antropogen prosesləri öyrənilərək təhlil olunmuş, torpaqların qiymətləndirilməsində aqroistehsalat qruplaşdırılmasında istifadə olunmuşdur.

Nəticədə Türkeş çökəkliyi ərazisində torpaqlarıdan mədəni-təbii bitkilər altında səmərəli istifadə etmək məqsədi ilə muxtar respublikanın iqtisadi-sosial şəraitinin yaxşılaşdırılması üçün təşkilati, mühəndis-texniki, informasiya texnoloji və sistemli tədbirlərin həyata keçirilməsi məqsədəuyğun sayılmışdır.

**Abstract**

The article presents information on the relevance of the topic, the object of research, its purpose, materials and methodology, as well as the eco-geographical conditions of the soils of the Türkeş Depression located in the low-mountain area of the Autonomous Republic. In the main part of the study, the physical-geographical factors influencing the formation of the soil environment of the area, including degradation processes as well as natural and anthropogenic processes, were studied and analyzed, and the results were used in the agro-production grouping applied in soil evaluation.

As a result, in order to ensure the efficient use of the soils of the Türkeş Depression under cultivated and natural vegetation, the implementation of organizational, engineering-technical, information-technological, and systematic measures aimed at improving the socio-economic conditions of the Autonomous Republic was considered appropriate.

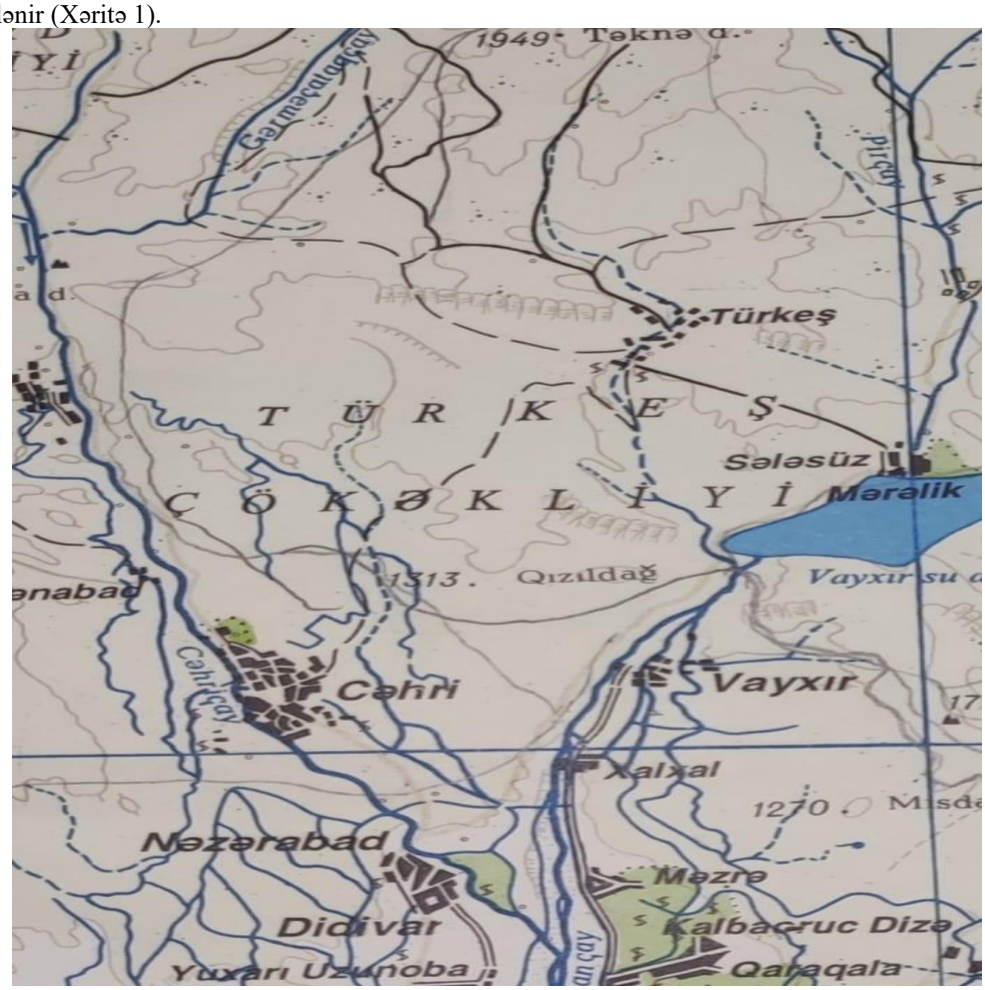
**Açar sözlər:** Torpaq, eko-coğrafi, relyef, geoloji qruluş, süxur, deqradasiya, təbii proseslər, antropogen proseslər, torpaqların qimətləndirilməsi, torpaqların aqroistehsalat qruplaşdırılması

**Keywords:** soil, eco-geographical, relief, geological structure, rock, degradation, natural processes, anthropogenic processes, soil evaluation, agro-production grouping of soils.

**Mövzunun aktuallığı.** Torpaq insan həyatında müstəsna əhəmiyyət kəsb edir. Naxçıvan MR mürəkkəb relyef şəraitinə malik olan dağlıq ərazi olduğuna görə kənd təsərrüfatına yararlı torpaq sahələri azlıq təşkil edir. Diğər tərəfdən ərazinin kontinental iqlim şəraiti torpaqların deqradasiyasına, eroziya və şorlaşma proseslərinə məruz qalmasına səbəb olur. Məhz, bu baxımdan muxtar respublikanın kənd təsərrüfatına yararlı torpaq fondunun 30 faizə qədərini təşkil edən Orta dağlıq qurşağın dağarası çökəkliklərindən biri olan Türkeş çökəkliyində yayılan torpaqların deqradasiya proseslərinə məruz qalır.

Türkeş çökəkliyi Naxçıvan MR-də coğrafi mövqeyinə görə şimaldan Dərələyəz dağlarının cənub ətəkləri, qərbdən Cəhriçayın, şərqdən Pirçayın

suayrıcıları, cənub-şərqdən isə Naxçıvançayın vadisi ilə sərhədlənir (Xəritə 1).




*Xəritə 1. Türkeş çökəkliyinin relyef xəritəsi*

Naxçıvan Muxtar respublikasının əhalisinin əksəriyyəti (təxminən 70 faizi) kəndlərdə yaşayır və kənd təsərrüfatı ilə məşğul olur. Hazırda muxtar respublikada il ərzində yaradılan əlavə dəyərin orta hesabla üçdə bir hissəsi kənd təsərrüfatının payına düşür. Azərbaycanda ilk dəfə olaraq torpaq islahatının Naxçıvanda keçirilməsi, torpağın şəxsi mülkiyyətə verilməsi, kolxoz və sovxozların əmlakının özəlləşdirilməsi, burada digər sahələrlə müqayisədə kənd təsərrüfatında islahatların daha sürətlə aparılmasına imkan yaratmışdır. Bu dövr ərzində əldə olunmuş müsbət meyilli dəyişikliklərin dinamikliyini təmin etmək, qarşıya çıxan problemləri aradan qaldırmaq məqsədilə müvafiq qanun və fərmanlar qəbul edilmişdir.

Hazırda muxtar respublikada həyata keçirilmiş aqrar islahatların nəticəsində özəl mülkiyyətə əsaslanan aqrar münasibətlərin formalaşması prosesinin ilk mərhələsi başa çatdırılmışdır. Qeyd olunan proseslərin keyfiyyətcə daha yüksək mərhələyə keçidini, müasir tipli aqrar-sənaye sektorunun formalaşmasını təmin etmək məqsədilə sistemli tədbirlər görülməkdədir. Bu mühüm tədbirlərdən mütəşəkkil ticarətin təşkilinin dövlət tərəfindən dəstəklənməsi, əsas ərzaq məhsullarının zəruri səviyyədə istehsal olunmasına şəraitin yaradılması, yerli və xarici mənşəli ərzaq məhsullarının keyfiyyətinə səmərəli nəzarət mexanizminin tətbiqi və ərzaq bazarında ekoloji, sanitar, baytar və fitosanitar tələblərinə cavab verməyən məhsul və xidmətlərin qarşısının alınması, kənd təsərrüfatı məhsullarının ixracına dövlət himayəsi və bu sahədə fəaliyyət göstərən təsərrüfat subyektlərinə güzəştli kreditlərin, lizinq obyekti olan texnikaların verilməsi hazırda daha çox önəm verilən istiqamətlərdəndir.

17 sentyabr 2008-ci il tarixdə təsdiq olunmuş "2008-2015-ci illərdə Naxçıvan Muxtar Respublikasında əhalinin ərzaq məhsulları ilə etibarlı təminatına dair Dövlət Proqramı" kənd təsərrüfatı məhsullarının istehsalının artırılmasında yeni istiqamətləri müəyyənləşdirmişdir. Naxçıvan Muxtar Respublikasında iqlim şəraiti və torpaq xüsusiyyətləri, eyni zamanda daxili tələbat nəzərə alınaraq əkinçilik həmişə ön planda olmuşdur. Muxtar respublikada taxılçılığın inkişafına xüsusi diqqət və qayğı göstərilmiş, taxıl əkinçilərinə kreditlər verilmişdir.

Muxtar respublikada, o cümlədən Türkeş çökəkliyində yararlı torpaq sahələrinin az olması, diğər tərəfdən ərazi muxtar respublikanın digər rayonlarına nisbətən dağlıq olduğuna görə torpaqların deqradasiyasına, xüsusilə eroziya proseslərinə məruz qalmasına səbəb olur. Ona görə də ərazidə torpaqlatrdan maksimum dərəcədə səmərəli istifadə etmək lazımdır. Məhz, bu baxımdan muxtar respublikada əkin altında istifadə olunan yararlı torpaqların az olması ilə əlaqədar olaraq ərazidə müasir

üsullarla torpaq-bitki tədqiqatların aparılması vacib məsələlərdən biridir.

Məhz, bu baxımdan muxtar respublikada "Türkeş çökəkliyi torpaqlarının eko-coğrafi şəraiti" mövzusunun seçilməsi aktuallıq təşkil edir.

**Tədqiqatın məqsəd və vəzifələri.** İşin əsas məqsədi Türkeş çökəkliyi torpaqlarının eko-coğrafi şəraitini iqtisadi-coğrafi baxımdan tədqiq etməkdən ibarətdir. Tədqiqat işində problemin həlli üçün aşağıdakı məsələlər qarşıya qoyulmuş və həll olunmuşdur.

- Mövzuya aid ədəbiyyat, xəritə materiallarının toplanması və mövcud metodikaların seçilməsi;
- Tədqiqat aparılacaq sahələrə maşrutların vaxtının və müddətinin müəyyənləşdirilməsi:
- Türkeş çökəkliyində yayılan torpaqlar qiymətləndirilərək, onların təsərrüfat əhəmiyyətini müəyyənləşdirmək;
- Tədqiqat işinin nəticələri təhlil olunaraq, Türkeş çökəkliyində torpaq münbitliyinin qorunması üçün bir neçə tövsiyə, təklifl və tədbirlərin hazırlanması;
- Nəticə və istifadə olunan ədəbiyyat materiallarının siyahısının hazırlanması;

**Tədqiqat obyekti.** Tədqiqat 2025-2026-cı illər ərzində Şahbuz inzibati rayonun Türkeş çökəkliyi oroqrafik vahidi ərazisində aparılmışdır.

**Tədqiqatın metodikası.** Tədqiqat işində qarşıya qoyulmuş problemlərin elmi-nəzəri məsələlərinə və metodologiyasına uyğun olaraq elmi-tədqiqat işi üç mərhələdə aparılmışdır.

1. Kameral-hazırlıq;
2. Çöl-laboratoriya;
3. Ümumiləşdirici-yekunlaşdırıcı;

Tədqiqat işinin yerinə yetirilməsində xarici, xüsusilə MDB və Azərbaycanın tanınmış torpaqşünas, aqroximik, coqrafiya və iqtisadiyyat sahəsində çalışan alimlərinin mövcud ədəbiyyatlarından, metodik vəsaitlərindən istifadə olunaraq aşağıdakı göstərilən üsullardan istifadə olunmuşdur.

**Təhlil və müzakirə.** Tədqiqat obyektində torpaq mühitinin formalaşmasına fiziki-coğrafi və antropogen amillər xüsusilə böyük təsir edir. Bu baxımdan tədqiqat işində ilk növbədə torpaq mühitinin formalaşmasına təsir göstərən fiziki-coğrafi amillərə diqqət yetirək.

Əvvəldə qeyd etdik ki, tədqiqat obyektində torpaq mühitinin formalaşmasına xüsusilə böyük təsir edən fiziki-coğrafi amillərdir. Bu amillərdən torpaq mühitinin formalaşmasına təsir göstərən amillərdən ərazinin relyef və geoloji quruluşu qeyd etmək olar [1]. İlk növbədə torpaqlarının formalaşmasına təsir göstərən təbii amillərdən ərazinin relyef quruluşu haqqında məlumat verilir.

**Relyefi.** Göstərilən amillər içərisində Türkeş çökəkliyində torpaqların formalaşmasında daha çox rol oynayan ərazinin relyef quruluşudur. Naxçıvan Muxtar Respublikası dağlıq ölkə olduğundan relyef quruluşu nəinki əkinaltı torpaqların, hətta başqa fiziki-coğrafi amillərin də (iqlim, bitki, heyvan və b.) formalaşmasında mühüm rol oynayır. Məhz, bu baxımdan relyef quruluşunu fiziki-coğrafi amillərin ən mühüm amil kimi saymaq olar. Muxtar respublikada bu istiqamətdə demək olar ki, ətraflı tədqiqat işləri aparılmamışdır.

Muxtar respublikanın, o cümlədən tədqiqat obyektinin relyef quruluşu müxtəlif məqsədlər bir çox tədqiqatçılar tərəfindən öyrənilmişdir. Lakin bu tədqiqatçılardan xüsusilə B.Ə. Budaqovun və S.Y. Babayevin xidmətlərini göstərmək olar. B.Ə. Budaqov və S.Y. Babayevin bu sahədə apardıqları tədqiqatlar aqrar istiqamətində olduğu üçün onları xüsusi qeyd etmək lazımdır. Relyef quruluşu üzrə yuxarıda qeyd etdiyimiz tədqiqat işi aparan alimlər Naxçıvan Muxtar Respublikasında bir neçə (4, 5, 6) hündürlük qurşaqları ayırmış və ərazidə düzənlik, dağətəyi, dağ, dağarası çökəklik, çay yataqları, dağ, çay terrasları, kuest, yarğan, qobu və b. formaların olduğunu göstərmişlər [1, s. 23-64].

1. Düzənlik qurşağı 600-1000 metr;
2. Alçaq dağlıq qurşağı 1000-1500 metr;
3. Orta dağlıq qurşağı 1500-2300 metr;
4. Yüksək dağlıq qurşaq 2300-3906 metr.

Naxçıvan Muxtar Respublikasının hündürlük qurşaqları üzrə torpaq örtüyü strukturunun, geomorfoloji və bioekoloji xüsusiyyətləri haqqında növbəti bölmədə daha ətraflı məlumat veriləcəkdir. Burada qısa da olsa onu qeyd etmək lazımdır ki, göstərilən hündürlük qurşaqlarında torpaqəmələgəlmə prosesi müxtəlif şəraitdə getdiyinə görə düzənlik, çökəklik və çay yataqlarına yaxın olan terraslarda torpaq qatı qalın, dağ yamac və zirvələrində nazik, orta və yüksək dağlığın yuxarı hissələrində bərk süxurların üzə çıxdığı müşahidə olunur.

**Geoloji quruluşu.** Əvvəldə qeyd etdik ki, Türkeş çökəkliyində torpaqların formalaşmasına təsir göstərən fiziki-coğrafi amillərdən biri də ərazinin geoloji quruluşudur. Ərazinin relyef quruluşu ilə bərabər geoloji quruluşu da bir çox alimlər tərəfindən öyrənilmişdir. Lakin, bu tədqiqatçılardan fərqli olaraq regionun geoloji quruluşunu ətraflı surətdə Ş.Ə.Əzizbəyov öyrənmişdir [2, s.85-113]. Tədqiqat obyektinin geoloji quruluşuna nəzər saldıqda görünür ki, burada torpaqların formalaşmasında əsasən qədim və müasir dövrün çöküntüləri rol oynayır. Göstərilən çöküntülər yaranma dövründən və şəraitindən asılı olaraq litoloji tərkiblərinin müxtəlifliyi ilə fərqlənir. Burada qumlar, çınqıl, andezit, bazalt, konqlomerat, vulkanoitlər, gilli-bitumlu, əhəngdaşı və digər süxurlar yayılmışdır. Bu süxurlar torpaqəmələgəlmə prosesinin istiqamətini göstərməklə, müxtəlif torpaq tiplərinin formalaşmasında da iştirak edir. Ərazidə vulkanogen çöküntülərin və çökmə süxurların mövcud olduğu sahələrdə aşınma prosesləri şiddətli gedir. Dağların yamaclarında vulkanogen süxurların yayıldığı sahələr isə qalın dellüvial çöküntülərlə örtülmüşdür. Orta dağlıq qurşağın əsas hissəsi respublikanın mərkəzində yerləşməklə şiddətli parçalanmışdır (Türkeşçay). Orta dağlıq qurşaqda ançaq Türkeş kəndi yerləşir.

**İqlimi.** Tədqiqat obyektində torpaq mühitinin formalaşmasına təsir göstərən fiziki-coğrafi amillərdən biri də ərazinin iqlim şəraitidir. Ölkəmizin, o cümlədən Türkeş çökəkliyinin iqlim şəraiti də müxtəlif məqsədlər üçün bir çox tədqiqatçılar tərəfindən öyrənilmişdir [1, s. 7-25].

Məlumdur ki, iqlim amili bitkilərin inkişafına birbaşa, torpaqlara isə dolayı yolla təsir göstərir. Ona görə də bu amilin də torpaqların qiymətləndirilməsində

nəzərə alınması vacib məsələlərdən biridir. Torpaqəmələgəlmə prosesində iqlim göstəricilərindən istilik və atmosfer çöküntüləri əsas rol oynayır. Çünki, bitkilərin vegetasiya dövründə torpaqda $10^0$ C-dən yuxarı temperaturların cəmi və rütubətlənmə dərəcəsi normal olmalıdır.

Naxçıvan Muxtar Respublikasında iqlim amillərini öyrənən alimlərdən fərqli olaraq, P.S.Mirzəyevin tədqiqatları xüsusi ilə maraq doğurur. Belə ki, o ərazinin iqlim amillərini aqrar sahənin inkişafı istiqamətində öyrənmişdir.

Biz də öz tədqiqat işimizdə P.S.Mirzəyevin tədqiqatlarından bəhrələnmişik. Beləliklə, muxtar respublikada iqlim ehtiyatları üzrə aparılan və apardığımız tədqiqatların nəticələrini ümümiləşdirərək, ərazinin coğrafi şəraitinin müxtəlifliyindən asılı olaraq hündürlük qurşaqları üzrə 6 iqlim tipinin olmasını müəyyən etdik. Bu iqlimin 3-4-sü Türkeş çökəkliyinin ərazisinə aiddir [2, s.81-97].

1. Qışı soyuq, yayı quraq, isti yarımsəhra və quru çöl iqlimi. 2. Qışı mülayim, yayı quraq, isti yarımsəhra və quru çöl iqlimi. 3. Yayı quraq və sərin keçən mülayim isti iqlim. 4. Yayı quraq və ən çox sərin keçən soyuq iqlim. 5. Dağ tundra iqlimi. 6. Nival iqlim tipi

İqlim tipləri üzrə apardığımız araşdırmalardan aydın olur ki, ərazidə şaquli zonallıq üzrə iqlim göstəriciləri düzənlikdən yüksək sahələrə doğru dəyişərək özünəməxsus xüsusiyyətlər yaradır. İqlimin yaratdıqları bu ərazi fərqləri relyef quruluşunda olduğu kimi əkinaltında torpaqların torpaqəmələgəlmə prosesinə müxtəlif təsir göstərir. Ərazinin ayrı-ayrı iqlim tiplərində formalaşan orpaq tiplərinin münbitliyində də fərqlər yaranır. Ona görə də hmüxtəlif tər bir hündürlük qurşaqları üzrə torpaqlardan mədəni bitkilər altında səmərəli istifadə etmək üçün qeyd olunan iqlim göstəricilərinə diqqət yetirmək tələb olunur. Qeyd etdimiz iqlim tipləri Əbrəqunus çökəkliyinın alçaq və orta dağlıq sahələrində çoxlu miqdarda istilik tələb etməyən payızlıq buğda əkilir. Sahədən payızlıq buğda yığıldıqdan sonra ərazidə 2000-2500$^0$C istilik ehtiyatı qalır. Bu isə düzənlik və alçaqdağlıq sahələrdə qısa vegetasiyalı tərəvəz və yem bitkiləri yetişdirmək hesabına ildə 2 dəfə məhsul götürməyə imkan verir. Bu sahələrdə yüksək məhsul əldə etmək və ərazidə torpaq münbitliyini qorumaq üçün yerli şəraitə uyğun tez yetişən buğda sortlarından əlavə, orta və gec yetişən sortların əkilməsi məsləhətdir.

**Hidroloji şəraiti.** Türkeş çökəkliyində su ehtiyatı mədəni bitkilərin inkişafında mühüm rol oynamaqla bərabər, təbii bitkilərin formalaşmasında münbitlik faktoruna da təsir göstərir. Naxçıvan Muxtar Respublikasında su ehtiyatlarının öyrənilməsində S.H.Rüstəmov, S.Y.Babayev, N.S.Bababəyli, Ə.G.Quliyev və b. tədqiqatçıları göstərmək olar [2, s.54-65].

Göstərilən tədqiqatçılardan S.H.Rüstəmovun, S.Y.Babayevin və Ə.G.Quliyevin Naxçıvan Muxtar Respublikasında su ehtiyatlarının əsas hissəsini tutan çaylar, göllər, su anbarları və yeraltı sular (kəhriz, bulaq) üzrə apardıqları tədqiqat işlərini xüsusi qeyd etmək lazımdır. Su ehtiyatı ərazidə hidroqrafik şəbəkə yaradır. Hidroqrafik şəbəkə insanların təsərrüfat fəaliyyəti ilə dəyişir. Bu isə torpaqların ərazidə formalaşmasına təsir göstərməyə bilməz. Məhz, buna görə də təsərrüfatlarda su ehtiyatlarından səmərəli istifadə etmək üçün onları düzgün istiqamətə yönəltmək lazımdır.

Son dövrlərdə Naxçıvan Muxtar Respublikasında, o cümlədən Türkeş çökəkliyində bu istiqamətdə bir sıra tədbirlər həyata keçirilmişdir. Lakin, ərazidə əkinə yararlı torpaqlardan səmərəli istifadə etmək üçün su ehtiyatları hələ də çatışmır. Ona görə də muxtar respublikada o cümlədən Türkeş çökəkliyində bu sahədə yeni su anbarlarının yaradılması üçün tədqiqatların miqyası artırılmalıdır.

Türkeş çökəkliyində su ehtiyatlarının toplanmasında kəhrizlərin də mühüm rolu vardır [1, s.77-78].

Qeyd olunanlarla bərabər, tədqiqat işində subartezian quyuları və kəhriz sistemləri ilə suvarılan əkin sahələrində istehsal edilən məhsula sərf edilmiş xərc, əmək fəaliyyəti və onların satış qiymətləri müqayisə edilmiş, kəhriz sistemlərinin arid zonalar üçün iqtisadi cəhətdən əlverişli su mənbəyi olması sübuta yetirilmişdir. Nəticədə kəhriz sistemlərinin doğrudan da iqtisadi cəhətdən səmərəli bir hidrotexniki qurğu olması, hətta iqtisadi nöqteyi-nəzərcə subartezian quyularından üstünlüyü sübut edilmişdir. Bu səbəbdən də mövcud kəhriz sistemlərinin qorunması və yeni kəhrizlərin qazılması öz aktuallığını saxlamaqdadır.

Beləliklə, tədqiqat obyektində aparılmış və apardığımız tədqiqatların nəticələri təhlil olunaraq müəyyən edilmişdir ki, ərazidə su ehtiyatlarının qeyri bərabər paylandığını və çatışmamazlığını nəzərə alaraq vahid su şəbəkəsinin yaradılması məsləhət görülür. Vahid su şəbəkəsinin funksiyası Şahbuz inzibati rayonunda mövcud olan Naxçıvançay, Badamlıçay, Türkeşçay və digər su obyektləri arasında əlaqə yaratmaqla, bir-birindən ehtiyacı olan ərazilərə kanallar və kəmərlər vasitəsilə suyu nəql etməkdən ibarətdir.

**Bitki örtüyü və heyvanlar ailəmi.** Məlumdur ki, Türkeş çökəkliyində torpaqların formalaşmasına formalaşmasında torpaq, bitki və heyvanlar aləminin xüsusi rolu vardır [10]. Ərazidə heyvandarlığın təbii yem bazasının formalaşmasında əvvəldə qeyd etdiyimiz ekoloji amillərlə bərabər torpaq, bitki və heyvanlar aləmi də xüsusi olaraq iştirak edir. Yem bazasının qiymətləndirilməsində göstərilən amillərin öyrənilməsi də vacib məsələlərdən biridir. İlk növbədə ərazidə yayılan torpaq-bitki örtüyünə nəzər yetirək.

Bildiyimiz kimi mürəkkəb relyef, müxtəlif torpaq və iqlim şəraiti olan dağlıq ərazimizin çox zəngin bitki örtüyü vardır. Naxçıvan Muxtar Respublikasının, o cümlədən Əbrəqunus çökəkliyin bitki örtüyü müxtəlif illərdə M.N.Abutalıbov, V.S.Hacıyev və son dövrlərdə isə T.H.Talıbov, Ə.Ş.İbrahimov və başqa tədqiqatçılar tərəfindən öyrənilmişdir [2, s.21-29].

Tədqiqatlar əsasında müəyyən olmuşdur ki, Türkeş çökəkliyində kontinental iqlimə malik olması ərazinin bitki örtüyünün formalaşmasına təsir göstərmiş və burada zəif, birtipli, yəni kserofit tipli bitkilərin inkişaf etməsinə səbəb olmuşdur. İqlimin belə kontinentallığı düzənlik və dağlıq hissələrə deyil, eyni zamanda az da olsa yuxarı dağlıq sahələrin bitki

örtüyünə də təsir göstərmişdir.

Beləliklə, ərazidə müxtəlif illərdə aparılan relyef, iqlim, torpaq, bitki və geobotaniki tədqiqatlar təhlil olunmuş, nəticədə ümümiləşdirilərək aşağıdakı torpaq-bitki zonalarının ayrılması məsləhət görülmüşdür.

1. Çöl torpaq-bitki örtüyü
2. Friqanoid torpaq-bitki örtüyü

Bu 2 bitki örtüyü əkinaltında demək olar ki, səmərəli istifadə olunur.

**Heyvanlar aləmi.** Türkeş çökəkliyində torpaqların formalaşmasına torpaq-bitki örtüyü ilə bərabər ərazidə yaşayan heyvanlar aləminin cuzi də olsadə mühüm rolu vardır. Üzvü maddələrin parçalanmasında heyvanlar aləminin içərisində onurğasız heyvanların və mikroorqanizmlərin fəaliyyəti əvəzedilməzdir. Məlumdur ki, torpaqda küllü miqdarda bakteriya qrupu, göbələklər, aktinomisetlər və onurğasız heyvanlar yaşayır.

Naxçıvan Muxtar Respublikasında, o cümlədən tədqiqat obyektində heyvanlar aləmi tarixin ayrı-ayrı inkişaf mərhələlərində müxtəlif tədqiqatçılar tərəfindən öyrənilmişdir. Lakin, tədqiqat işimizdə xüsusilə M.Ə.Musayevin, S.B.Əliyevin, M.Z.Piriyevin, H.T.Hüseynovun, X.N.Rüstəmov və R.V.Əmirovun əsərlərinə istinad olunmuşdur.

Torpağın üst qatında üzvi maddələrin çox olması bu qatda torpaq tipindən asılı olaraq bakteriyaların inkişafı üçün əlverişli şərait yarandığında bu maddələrin miqdarının azalıb, çoxalması məsələləri və həmçinin aşağı qatlara doğru miqdarı öyrənilmişdir.

Bildiyimiz kimi bakteriyalar üzvü birləşmələrdən qeyri-üzvi birləşmələr və ya prosesin əksinə getməsi, onların qidalanması və tənəffüsünün məhsuludur. Araşdırmalar nəticəsində tədqiqat işində torpaqda bakteriyaların qidalanma xüsusiyyətlərinə və tənəffüs elementlərinə də diqqət yetirilmişdir. Qidalanma xüsusiyyətlərinə görə bakteriyalar 2 qrupa (prototrof və metatrof) bölünür.

Torpaq mikroorqanizmləri arasında göbələklər, şibyələr və mamırlar torpaqəmələgəlmə prosesində bioloji aşınmanı sürətləndirməklə, ilk əmələgələn torpağı P, S, K, Ca, N və başqa elementlərlə zənginləşdirir.

Torpaqda üzvü maddələrin əmələgəlməsində onurğasız və onurğalı heyvanlar da iştirak edir (müxtəlif soxulcanlar, mikroorqanizmlər, siçanlar, sürünənlər, quşlar, dırnaqlı heyvanlar və s.). Ərazinin bitki örtüyündən, çürüntünün miqdarından və becərilmə şəraitindən asılı olaraq soxulcanların və mikroorqanizmlərin miqdarı dəyişilir. Məsələn bu, palıd meşəsi altında olan torpaqların 1 hektarında 2940 ton oldugu halda, ot qarışığı əkilən torpaqlarda 320 ton təşkil edir. Çoxillik elmi tədqiqat işlərinin nəticələri göstərmişdir ki, sahələrə norma üzrə gübrələrin verilməsi torpaqların bioloji fəallığını artırır.

Bu bölmədə Şahbuz inzibati rayonun bir oroqrafik vahidi olan Türkeş çökəkliyində torpaqlarının formalaşmasına təsir göstərən antropogen deqradasiya prosesləri haqqında ayrı-ayrılıqda məlumat verilir [2, 3].

Tədqiqat obyektində torpaqəmələgəlmə prosesində əvvəldə göstərilən faktorlarla bərabər təbii deqradasiya proseslərini və insan amilini də xüsusi qeyd etmək lazımdır. Antropogen relyef insan fəaliyyəti ilə dəyişdirilmiş və yaradılmış relyefdir. Qədim zamanlardan insan yaranandan sonra uzun əsrlər boyu ətraf mühitə çox yönlü fəaliyyəti nətıcəsində torpaq və bitki örtüyündə dərin izlər buraxmışdır. İlk mərhələdə təbii landşaftlar bir çox hallarda mədəni bitki landşaftına, yəni aqrolandşaftlara çevirilmişdir.

Təbii deqradasiya proseslərinin və insanların təbiətə səriştəsiz, vəşicəsinə müdaxiləsi nəinki muxtar respublika ərazisində baş vermiş, hətda Türkeş çökəkliyində də belə neqativ hallara tez-tez rast gəlinir. Bu cür neqativ hallar hal-hazırda da ərazidə davam etməkdədir.

Qeyd olunan təbii deqradasiya prosesləri, antropogen deqradasiya prosesləri torpaqların münbitliyinin azalmasına və əkin dövriyyəsindən çıxmasına nəinki tək-tək, hətda bəzi ərazilərdə kompleks şəkildə təsir göstərirlər.

Apardığımız tədqiqatların və ədəbiyyat materiallarının nəticələrindən aydın olur ki, torpaqların formalaşmasına təsir göstərən amillərdən təbii deqradasiya proseslərini və antropogen təsiri aşağıdaki kimi qruplaşdırmaq olar.

I. Təbii deqradasiya proseslərinə: Eroziya proseslərindən, su və külək, iqlimin dəyişməsinə istiləşmə və quraqlıq, şoranlaşma və şorakətləşmə, daşlıqlar və kol-kos basmış sahələri aid etmək olar.

II. Antropogen təsirə: Ərazidə əhalinin sıxlığı, otarma, ağac və kolların qırılması, torpaqlardan həddindən artıq istifadə olunması (dehumifikasiya prosesi), suvarma, irriqasiya eroziyası və irriqasiya yarğanlarının yaranması, torpaqların mexaniki işlərlə pozulması və dağılması, nəqliyyat, tikinti və faydalı qazıntıların geoloji kəşfiyyatı, hasilatı və nəql olunması, pestisidlərin, radioaktiv maddələrin, gübrələrin və s. göstərmək olar.

I. Təbii deqradasiya prosesləri. Türkeş çökəkliyində qeyd olunan təbii deqradasiya proseslərindən müxtəlif dərəcələrdə külək və su eroziya baş verir, İqlimin dəyişməsi təbii şəraitin bütün komplekslərinə təsir göstərir. İqlim elemenlərindən istiləşmə nəticəsində temperaturun yüksəlməsi ekosistemdə quraqlıqların baş verməsinə, hidrorejimin dəyişməsinə, buxarlanmanın yüksəlməsinə və yağıntıların azalmasına səbəb olur. Quraqlıq isə istiləşmə nəticəsində ərazidə quraqlıq başlayır. Quraqlıq yağıntısı çox olan bölgələrə nisbətən inzibati rayonun ekosisteminə daha çox təsir göstərməklə səhralaşma və torpaq deqradasiyası prosesini gücləndirir. Çünki, bu yağıntısı az düşən və quraq ərazilərdən biridir (Şəkil 1, 2.).


*Şəkil 1, 2. Türkeş çökəkliyində eroziya və quraqlıq prosesləri*

Ərazidə təbii deqradasiya proseslərindən biri də şoranlaşma, şorakətləşmə və bataqlıqlaşmadır. Türkeş Əbrəqunus çökəkliyində az-çox çayların kənarlarında və çökək sahələrdə şoranlaşma və bataqlıqlaşma prosesləri həm təbii və həmdə insanların səriştəsiz təsirləri nəticəsində baş verir və bunların əsasında torpaqlar öz münbitliyini itirərək əkin dövrüyyəsindən çıxır.

Tədqiqat obyektində torpaq münbitliyinin azalmasına mənfi təsir göstərən qeyd etdiyimiz mənfi təbii amillərlə bərabər, ərazidə baş vermiş güclü sellər nəticəsində müxtəlif ölçülərdə daşlıq və quraqlıqla əlaqədar kol-kos basmış strukturu pozulmuş torpaqlara da rast gəlinir Daşlarla örtülmüş və kol-kos basmış strukturu pozulmuş belə torpaqlar Dərələyəz dağlarının ətəklərində və ona perpendikulyar şəkildə uzanmış Cəhriçay, Badamlıçay orta yüksəklikli suayrıcı dağların ətəklərində və Türkeşçayın orta axarlarının yataqlarında müşahidə olunur.

II. Antropogen təsir. Səhralaşma torpaq deqradasiyasını yaradan səbəblər arasında təbii amillərlə yanaşı, antropogen təsirlər də əsas diqqət çəkən məsələlərdən biridir (M.Babayev). Antropogen təsir ətraf mühitə, o cümlədən torpağa təsir göstərən insan fəaliyyətinin müxtəlif formalarını birləşdirir. Müxtəlif formalarda insanların torpaqlara kortəbii münasibəti bir çox hallarda ərazidə eroziya proseslərinin inkişafını sürətləndirir və bataqlıq sahələri yaradır. Məsələn, sahələrdə heyvanların sistemsiz otarılması, ağac və kolların qırılması eroziya proseslərini sürətləndirən əsas amillərdəndir. Tədqiqat obyektində səhralaşma və torpaq deqradasiyasını yaradan antropogen amillərin müxtəlif formalarından biri olan əhalinin ərazidə məskunlaşmasına diqqət yetirək.

Əhalinin ərazidə məskunlaşmasının torpaqlara təsirinə nəzər saldıqda, burada əhali o qədər də sıx olmasada torpaq münbitliyinə təsir göstərən əsas faktorlardan biridir. Ona görə bu ərazilərin torpaqları öz münbitliyini get-gedə itirərək deqradasiya proseslərinə uğrayaraq əkin dövriyyəsindən çıxır. Lakin, çökəliyin torpaqları yarımsəhra torpaqlarına nisbətən öz münbitliyi ilə seçilir. (Şəkil 3, 4).


*Şəkil 3, 4. Yararlı torpaq sahələrindən istifadə olan sahələr*

Ərazidə torpaq münbitliyinin azalmasına təsir göstərən əhali sıxlığı ilə bərabər, qış və yay otlaqlarında heyvanların sistemsiz otarılması, ağac və kolluqların qırılması hallarına rast gəlinir Eyni zamanda ərazidə torpaqlardan mədəni və təbii bitkilər altında istifadə olunarkən aqrotexniki qaydalara düzgün riayət etməmək nəticəsində münbitliyi azalaraq məhsuldarlıq ilbə-il aşağı düşür. Toraqlardan uzun müddət istifadə olunması və suvarma sularının nəzarətsiz buraxılması nəticəsində aşağıda qeyd olunan mənfi hallara gətirib çıxarır.

Torpaqlardan fasiləsiz olaraq bəzi təsərrüfatlarda torpaqlardan eyni bitki altında uzun illər fasiləsiz olaraq istifadə olunur. Bu da torpaqların fiziki, kimyəvi

xüsusiyyətlərini pisləşdirir və bitkilərin məhsuldarlığının aşağı düşməsinə səbəb olur.

Ərazidə mənfi antropogen amillərindən biri də nəzarətsiz suvarma nəticəsində torpaqlarda baş verən irriqasiya eroziyasıdır. Dağətəyi və aran rayonlarında suvarılan sahələrdə su eroziyasının başqa bir növü olan irriqasiya eroziyası yayılmışdır. Bu proseslər nəticəsində torpaqların üst münbit hissəsi yuyularaq, dərin şırım və yarğanlar yaranaraq torpaqlar yararsız hala düşür.

Suvarma normadan artıq olduqda suyun bir hissəsi torpağa hopur, qalan hissəsi isə yamac uzunu axaraq torpağın narın münbit qatını yuyub aparır.Yuyulub aparılmış torpaq sahənin aşağı hissəsində çökür, müxtəlif qalınlıqda qaysaq əmələ gəlir. Bu yerlərdə torpağın su-hava rejimi pisləşir.

Əkin sahələrində irriqasiya eroziyasının əmələ gəlməsinə suvarma vaxtı arxın daima bir yerdən açılması da böyük təsir göstərir. Bununla yanaşı sahələrin çox girintili-çıxıntılı olması qobuların əmələ gəlməsinə şərait yaradır. Suvarmanı ikinci bir tərəfdən nəzarətsiz buraxılan bu sular axmaz yerlərə toplanaraq bataqlıqlar yaradır. İrriqasiya eroziya və bataqlıqlaşma proseslərinə inzibati rayonun təsərrüfat sahələrində müşahidə olunur.

Mənfi antropogen təsirlərdən biri də ərazidə plansız nəqliyyat yolları, tikinti materialları, mədən sənayesinin hasilatıdır. Bu neqativ hallara plansız nəqliyyat yolları, çay yataqlarından və bəzi dağlıq, dağətəyi və düzənlik sahələrdən qum və digər tikinti materiallarının daşınması, həmin ərazilərin yarğan şəkilində buraxılması nəticəsində deqradasiya uğramış torpaqlara da rast gəlinir (Şəkil 5, 6)

Türkeş çökəkliyinin cənub hissəsində Naxçıvan-Batabat magistral yolunun alt və üst hissələrində axın istiqaməti olmayan suların yığılması sayəsində bataqlıq sahələr yaranır və yaxud torpaqlar quruyaraq öz münbitliyini itirir. Bundan əlavə rayon ərazisində ətraf sahələrə lazım olmayan tikinti materialları və məişət tullantıları hesabına çirklənən torpaqlara da rast gəlinir

Əvvəldə qeyd olunduğu kimi mövzuya aid ədəbiyyat, çöl materialları toplanılmış və işin metodikası hazırlanmış və mövzu işlənərkən tarixin ayrı-ayrı inkişaf mərhələlərində xarici ölkələrdə, o cümlədən Azərbaycan və Naxçıvan Muxtar Respublikasında torpaq-bitki tədqiqatları aparan alimlərin monoqrafiya, metodik vəsait, xəritə materialları və müasir tələblərə cavab verən iş təcrübələrindən istifadə olunmuşdur [3, 4, 5, 6, 7, 8, 9, 10].

Mövzunun yerinə yerinə yetirilməsində ədəbiyyat materialları ilə bərabər əsas məsələlərdən biri də çöl materiallarının toplanmasıdır. Bu məqsədlə Əbrəqunus çökəkliyində torpaq örtüyü struktur tərkibinin öyrənilməsi üçün əraziyə aşağıda göstərilən istiqamətlər üzrə ekspedisiyalar təşkil olunmuşdur.

Aparılan müşahidələr əsasında tədqiqat obyektində aşağıdaki torpaqların tip, yarım tip və növmüxtəlifikləri müəyyənləşdirilmişdir [5, s.45-62; 9]. Bu torpaq növmüxtəlifliklərindən xüsusi olaraq boz, qədimdən suvarılan-boz, allüvial-boz, boz-qonur, açıq-qəhvəyi (şabalıdı), qəhvəyi (şabalıdı), çəmən-bataqlıq, çay subasarları, və allüvial-çəmən torpaqlarını göstərmək olar.

2025-cu ilin oktyabr və 2026-cı ilin apel-may aylarında Türkeş çökəkliyinə təşkil olunmuş ekspedisiyalar nəticəsində toplanmış materialların təhlili əsasında qeyd olunmuş torpaq növmüxtəliklərindən nümunələri götürülmüş ətrafında yayılan sahələrdə mədəni və təbii bitkilərin məhsuldarlığı öyrənilmişdir (Cədvəl 1).

Cədvəl 1

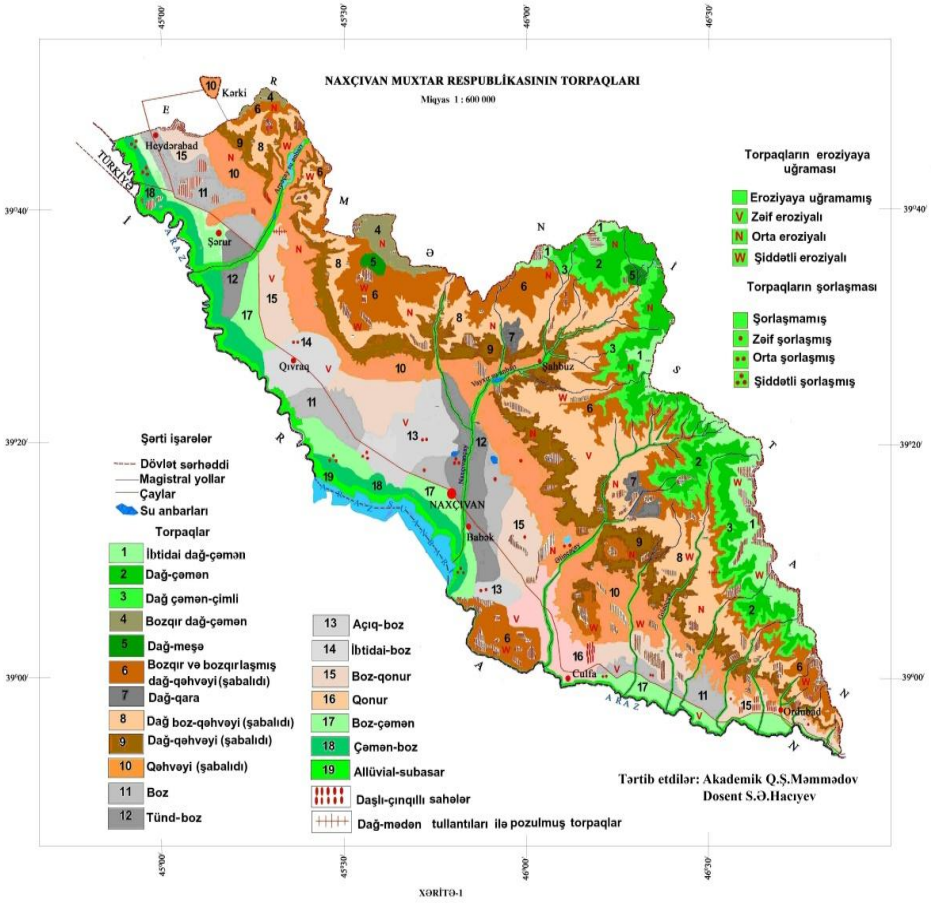
Türkeş çökəkliyində müəyyən olunmuş sahələrdə 2025-26-cı ilin məlumatlarına dair mədəni və təbii bitkilərin məhsuldarlığı (s/ha)

| № | Torpaqların adı | Taxıl | Yonca | Təbii otlar |
|---|---|---|---|---|
| 1. | Şabalıdı (qəhvəyi) | 45-50 | 150-155 | 6-7 |
| 2. | Subasar allüvial | 40-45 | 145-150 | 5-6 |
| 3. | Açıq-şabalıdı (qəhvəyi) | 35-40 | 140-145 | 4-5 |
| 4. | Qumsal açıq-şabalıdı(qəhvəyi) | 30-35 | 135-140 | 3-4 |
| 5. | Yüngül gilliceli yuxa, şabalıdı (qəhvəyi), | 25-30 | 130-135 | 2-3 |
| 6. | Bozqırlaşmış şabalıdı (qəhvəyi) | 15-20 | 125-130 | 1-2 |

Türkeş çökəkliyində müəyyən olunmuş sahələrdə 2025-26-cı ilin məlumatlarına dair mədəni və təbii bitkilərin məhsuldarlığına (s/ha) diqqət yetirildikdə görünür ki, ərazidə ən yüksək məhsuldarlıq şabalıdı (qəhvəyi) və subasar allüvial, ən aşaöı məhsuldarlıq isə bozqırlaşmış şabalıdı (qəhvəyi)torpaqlarda müşahidə olunmuşdur.

Ərazidə torpaqların mədəni və təbii bitkilər altında qiymətləndirilməsində torpaq-bitki nümunələrinin morfoloji, fiziki və kimyəvi xüsusiyyətləri ilə bərabər, onların eko-coğrafi şəraitinə (relyef, geoloji və geomorfoloji quruluşu, iqlim şəraiti, hidroloji və hidrogeoloji şəraiti, bitki və heyvanlar ailəmi və s.) də diqqət yetirilmişdir [1, s. 23-85; 2, s. 9-59; 3, s. 26-29; 7, s. 5-38; 8, s. 151-184; 9, s. 112-123, 11, 12].

Tədqiq olunan sahələrin torpaq növmüxtəlifliyi öyrənilərkən dosent S.Ə. Hacıyev tərəfindən tərtib olunmuş Naxçıvan MR-in 1:150000 miqyaslı torpaq xəritəsindən istifadə olunmuşdur (Xəritə 2).




*Xəritə 2. Naxçıvan MR-in torpaq xəritəsi*

Ərazidə torpaqların mədəni və təbii bitkilər altında qiymətləndirilməsində Türkeş çökəkliyi torpaqlarının tam bonitet şkalası (100 ballı şkalaya görə) müəyyənləşdirilmişdir (Cədvəl 2).

Cədvəl 2

Türkeş Əbrəqunus çökəkliyi torpaqlarının tam bonitet şkalası
(100 ballı şkalaya görə)

| № | Torpaqların adı | Bonitet balı | Bal sinifi | Keyfiyyət qrupu |
|---|---|---|---|---|
| 1. | Şabalıdı (qəhvəyi) | 100 | X | I Yüksək |
| 2. | Subasar allüvial | 90 | X | |
| 3. | Açıq-şabalıdı (qəhvəyi) | 82 | IX | |
| 4. | Qumsal açıq-şabalıdı (qəhvəyi) | 76 | VIII | II Yaxşı |
| 5. | Yüngül gillicəli, yuxa, şabalıdı (qəhvəyi), | 72 | VIII | |
| 6. | Orta gillicəli şabalıdı (qəhvəyi) | 62 | VII | |
| 7. | Yüngül gillicəli, zəif şoranlaşmış, şabalıdı (qəhvəyi), | 56 | VI | III Orta |
| 8. | Qumsal, çınqıllı, allüvial-subasar | 52 | VI | |
| 9. | Qumsal, daşlı, allüvial-çəmən | 50 | V | |
| 10 | Qumsal, bataqlı çəmən-kol | 42 | V | |
| 11 | Qumsal, bataqlı-çəmən | 34 | IV | IV Aşağı |
| 12 | Daşlı-çınqıllı çay yataqları | 16 | II | V |
| 13 | Daşlı çay yataqları | 12 | II | Şərti yararsız |

2025-26-cı tədris ilində “Türkeş çökəkliyi torpaqlarının eko-coğrafi qiymətləndirilməsi” mövzusu üzrə apardığımız torpaq-bitki tədqiqatları əsasında müxtəlif mənbələrdən toplanmış materialların araşdırılması (morfoloji, fiziki, kimyəvi xüsusiyyətləri və ekoloji şəraiti) nəticəsində ərazidə 21 növmüxtəliflikləri aşkar olmuşdur. Göstərilən 21 növmüxtəlifliyi 13 tip və yarımtiplər üzrə birləşdirilərək, torpaqlar qiymətləndirilmiş və aqroistehsalat qruplaşdırılması aparılmışdır. Burada torpaqlar tam bonitet şkalaya əsasən 100, minimum isə 12 bal almışdır.

Bu torpaqlar müəyyən olunan əlamətlərinə görə müxtəlif keyfiyyətə və dəyərlilik əhəmiyyətinə malik olur, tam bonitet şkalanı tərtib etmək üçün «təshih» əmsallarından (şorlaşma, eroziya, qranulometrik tərkib və b.) da istifadə olunmuşdur.

**Nəticə**

1. Tədqiqat obyekti üzrə tərtib olunmuş aqroistehsalat qruplaşdırılması aqromeliorativ tədbirlərə ehtiyacı olan torpaq qruplarını da aşkar etməyə imkan verir. Bütövlükdə bu qruplaşdırma Türkeş çökəkliyində yayılmış bütün torpaq tipləri, yarımtipləri və növmüxtəlifliklərini birləşdirir.

2. Ərazi ekoloji şəraitin kompleksindən asılı olaraq torpaqlar daha kiçik taksonomik vahidlərə bölünür. Onların sonuncu bonitet balları əvvəldə qeyd etdiyimiz kimi (bataqlıqlaşma, şorakətləşmə, eroziya, qranulometrik tərkib və s.) «təshih» əmsallarının köməyi ilə müəyyən etmək mümkündür.

3. Tədqiqat obyektində torpaq tipinin balını və aqroistehsalat qrupunu bilməklə, təbii və mədəni bitkilər altında istifadə olunan torpaqların yaxşılaşdırılması üçün aqronomik tədbirlərin (meliorasiya, gübrələmə, eroziyaya qarşı tədbirlər, kol-kos və daşlardan təmizləmə, suvarma və s.) həyata keçirilməsini müəyyən etmək olur.

**Təkliflər**

1. Türkeş çökəkliyində torpaqlardan maksimum dərəcədə səmərəli istifadə etmək üçün ilk növbədə susuz sahələrə su kanalları çəkilməlidir.

2. Çökəkliyin çay sahilində az da olsa bataqlıqlaşmadan və şorakətləşmədən, şimal, şimal-şərq, şimal-qərb hissələrində isə eroziyadan qorumaq və münbitliyini bərpa etmək üçün çoxlu sayda ağac bitkilərinin əkilməsi məqsədilə tədbirlər həyata keçirilməlidir.

3. Fermer və fərdi təsərrüfatçılar torpaqlardan istifadə edərkən torpaq kartoqramlarına əsaslanmalı və mütəxəssislərdən daimi məsləhətlər almalıdır.

4. Çökəkliyin ekoloji şəraiti nəzərə alınmaqla meliorativ tədbirlər əsasında torpaqların potensial imkanlarından səmərəli istifadə etməklə yerli şəraitə uyğun daha məhsuldar bitkilər əkilməli və su ehtiyatından maksimum dərəcədə səmərəli istifadə olunmalıdır.

Göstərilən tədbirlər Türkeş çökəkliyində elmi əsaslarla planlı surətdə həyata keçirilərsə ərazidə torpaqlardan mədəni və təbii bitkilər altında səmərəli istifadə etmək olar.

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# MATHEMATICS

## RELATIONSHIPS BETWEEN VOLTERRA'S FIRST AND SECOND KINDS OF INTEGRAL EQUATIONS AND DIFFERENTIAL EQUATIONS

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**Abstract**
This article is devoted to the connection between linear differential equations and Volterra's integral equation. A method of approximating ordinary differential equations by reducing them to Volterra's integral equation is considered. On the contrary, it is shown by examples that the solution of Volterra's integral equation is the same as the solution of an ordinary linear differential equation. The uniqueness of the solution of Volterra's integral equation is shown by the fact that it admits only one solution at points that do not have singularities in the Cauchy problem.
**Keywords:** differential equation, integral equations, derivative, initial condition, Cauchy problem.

**Introduction.** When studying and studying many natural phenomena, we rely on their laws and, when applying them in life, we create mathematical models. For example, many problems in engineering, chemistry, physics, ecology and other fields are reduced to differential equations or integral equations. At the same time, their solutions are elementary functions. We will consider the method of reducing ordinary differential equations to Volterra's integral equation and approximating them [3]. It has been shown that equations with such relations can be solved by solving one and checking its solution using the other equation. If the solutions are unique and exist, then their solution can be demonstrated using the packages of the modern Maple program [1,2,5].

We assume that an ordinary second-order linear non-homogeneous differential equation is given by the initial conditions

$$L(y) \equiv y''(x) + p(x)y'(x) + q(x)y(x) = F(x),\ a < x < b, \tag{1}$$
$$y(x_0) = y_0,\ y'(x_0) = y_1,$$

where $q(x)$, $p(x)$, $f(x)-$ functions are continuous on segment $[a,b]$, $y = y(x)-$ is an unknown function $x_0 \in (a,b)$ and satisfies the following conditions

$$y(x) \in C[a,b] \cap C^2(a,b), \tag{2}$$
$$Ly(x) \equiv f(x),\ x \in (a,b), \tag{3}$$
$$y(x_0) = y'(x_0) = 0,\ x_0 \in (a,b). \tag{4}$$

To construct an integral equation equivalent to problem (2)-(4), we use the following

$$y''(x) = \varphi(x), \tag{5}$$

Integrate both sides of expression (5) from $x_0$ to $x$ to find $y(x)$, then

$$\frac{dy'}{dx} = \varphi(x) \Rightarrow dy' = \varphi(x)dx \Rightarrow \int_{x_0}^{x} dy'(t) = \int_{x_0}^{x} \varphi(t)dt \Rightarrow$$

$$\Rightarrow y'(t)\Big|_{x_0}^{x} = \int_{x_0}^{x} \varphi(t)dt \Rightarrow y'(x) = \int_{x_0}^{x} \varphi(t)dt + y_1 \tag{6}$$

Integrating again and using Dirichlet's formula, we get

$$y(x) = \int_{x_0}^{x} (x-t)\varphi(t)dt + y_1 x + y_0 \tag{7}$$

Taking into account (5)-(7), we write the differential equation (1) as follows

$$\varphi(x) + p(x)\left(\int_{x_0}^{x} \varphi(t)dt + y_1\right) + q(x)\left(\int_{x_0}^{x} (x-t)\varphi(t)dt + y_1 x + y_0\right) = f(x),$$

Making elementary changes

$$\varphi(x)+\int_{x_0}^{x}[p(x)+(x-t)q(x)]\varphi(t)dt=f(x)-y_1p(x)-(y_1x+y_0)q(x) \quad (8)$$

We obtain the Volterra integral equation of the second kind, which is:

$$K(x,t)=p(x)+(x-t)q(x),\ F(x)=f(x)-y_1p(x)-(y_1x+y_0)q(x),\ y_1,y_0\in R$$

Equation (8) has a continuous and unique solution at point $x=0$, and the Cauchy problem (1) has a solution and uniqueness.

Example 1. $y''(x)+y(x)=0$, $y(0)=1$, $y'(0)=0$ Reduce the Cauchy problem to an integral equation [4].

Subtract. We use the notation $\frac{d^2y}{dx^2}=\varphi(x)$. Then we integrate twice to find $y(x)$.

$$\frac{dy}{dx}=\int_0^x\varphi(t)dt+y'(0)=\int_0^x\varphi(t)dt,\ y(x)=\int_0^x(x-t)\varphi(t)dt+1.$$

Substitute the results of $\frac{d^2y}{dx^2}$ and $y(x)$ into the differential equation.

$$\varphi(x)+\int_0^x(x-t)\varphi(t)dt+1=0,$$

We obtain the Volterra integral equation of the second kind, where $K(x,t)=x-t$, $F(x)=-1$. We solve the equation by the method of successive approximations. For this, we choose $\varphi_0(x)=-1$ as the approximation to zero. Then

$$\varphi_1(x)=-1-\int_0^x(x-t)(-1)dt=-1+\int_0^x(x-t)dt=-1+(xt-\frac{t^2}{2})\Big|_0^x=-1+\frac{1}{2}x^2$$

$$\varphi_2(x)=-1-\int_0^x(x-t)\left(-1+\frac{1}{2}t^2\right)dt=-1+\int_0^x(x-\frac{xt^2}{2}-t+\frac{t^3}{3})dt=-1+\frac{1}{2!}x^2-\frac{1}{4!}x^4$$

We are approaching $\varphi_n(x)$.

$$\varphi_n(x)=-1+\frac{1}{2!}x^2-\frac{1}{4!}x^4+\ldots+(-1)^{n-1}\frac{1}{(2n)!}x^{2n}=\sum_{k=0}^{n}\frac{(-1)^k}{(2k)!}x^{2k}$$

From this we find the limit of $n\to\infty$ to find $\varphi(x)$.

$$\varphi(x)=\lim_{n\to\infty}\varphi_n(x)=\lim_{n\to\infty}\sum_{n=0}^{\infty}\frac{(-1)^n}{(2n)!}x^{2n}=\cos x$$

From this we obtain the solution of the integral equation 3. This solution is also a solution of the Cauchy problem.

Now we will solve this Cauchy problem in Maple, giving the necessary commands [5].

```
> restart;
de := diff(y(x), x$2) + y(x) = 0;
```

$$\frac{d^2}{dx^2}y(x)+y(x)=0$$

```
cond := y(0) = 1, D(y)(0) = 0;
```

$$y(0)=1,\ D(y)(0)=0$$

```
dsolve({de, cond}, y(x));
```

$$y(x)=\cos(x)$$

On the contrary, the derivation of Volterra's integral equation is the same as that of ordinary differential equations. The uniqueness of the derivation of Volterra's integral equation of the first and second kind follows from the fact that it can be derived only at points that are not singular by the Cauchy problem.

If the $y(x)=\lambda\int_a^x K(x,t)y(t)dt+f(x)$ integral equations have $K(x,t)$ kernels and $f(x)$ free terms with continuous derivatives with respect to the variable *x*, then this equation is differentiable one or more times. In these cases, it is possible to reduce Volterra's integral equation to the Cauchy problem.

Then the derivative of the integral is calculated using the formula

$$y'(x)=\frac{d}{dx}\left(\lambda\int_a^x K(x,t)y(t)dt+f(x)\right)=\lambda K(x,x)y(x)+\lambda\int_a^x\frac{\partial K(x,t)}{\partial x}y(t)dt+f'(x), \quad (9)$$

Example 2. $y(x)=x+1+\int_0^x y(t)dt$, $x\in R$ Find the solution of Volterra's integral equation in terms of a differential equation.

Derivation. Using the formula (9) of the given integral equation, we take the derivative of both sides with respect to the variable *x*.

$$y'(x)=(x+1+\int_0^x y(t)dt)'=1+y(x),\ y'(x)=1+y(x)$$

We get a differential equation that is separable in a first-order variable. Substituting $x=0$ into the integral equation, we get the initial condition $y(0)=1$. And the solution of this differential equation is

$$y'(x)=1+y(x)\Rightarrow\frac{dy}{dx}=1+y\Rightarrow\frac{dy}{1+y}=dx\Rightarrow\int\frac{dy}{1+y}=\int dx+\ln C\Rightarrow$$

$$\ln(1+y)=\ln e^x+\ln C\Rightarrow\ln(1+y)=\ln Ce^x\Rightarrow 1+y=Ce^x\Rightarrow y=Ce^x-1$$

Using the initial condition $y(0)=1$, we obtain the individual product $y=2e^x-1$.

*Check*. Let's substitute $y=2e^x-1$ individual derivatives into the integral equation

$$y(x)=x+1+\int_0^x y(t)dt.$$

$$2e^x-1=x+1+\int_0^x(2e^t-1)dt=x+1+(2e^x-t)\Big|_0^x=x+1+2e^x-x-2e^0-0=2e^x-1$$

Now we will solve this $y'(x)=1+y(x)$, $y(0)=1$ Cauchy problem in Maple [4].

```
> restart;
de := diff(y(x), x) - y(x) - 1 = 0;
```

$$\frac{d}{dx}y(x)-y(x)-1=0$$

```
cond := y(0) = 1;
```

$$y(0)=1$$

```
dsolve({de, cond}, y(x));
```

$$y(x)=-1+2\,e^x$$

We can get it with the drawing by giving the necessary commands.

*Example* 3. Reduce $y(x)=x+\int_0^t xty(t)dt$ integral equations to differential equations [6].

*Deduction*. We write this equation in the following form: If we denote $y(x)=x\left(+\int_0^t ty(t)dt\right)$ and $z(x)=1+\int_0^t ty(t)dt$, then we get the equation $y(x)=x\cdot z(x)$ (*). From the last notation, we get $z'(x)=\left(1+\int_0^t ty(t)dt\right)'=ty(x)\Rightarrow z'(x)=ty(x)$.

Taking into account (*), we obtain a differential equation that is separable in $z'(x) = x^2 z(x)$ ordinary variable. Therefore, the general solution of this differential equation is $z(x) = Ce^{\frac{x^3}{3}}$.

Note that when z(0) = 1, we find that C = 1. Thus, we obtain $y(x) = xe^{\frac{x^3}{3}}$ solutions of the original equation.

Example 4. Derive the initial problem for the differential equation.

$$y''(x) + y(x) = f(x),\ x \in R, \tag{10}$$

where $f(x)$ is a continuous function with function $x \in (-\infty,+\infty)$,

$$y(0) = y'(0) = 0, \tag{11}$$

by reducing it to an integral equation [6].

*Deduction*. In equation (10) $p(x) \equiv 0$ and $q(x) = 1$, $x_0$=0. Then, using formulas (10) and (11), we get the following

$$\varphi(x) + \int_{x_0}^{x} (x-t)\varphi(t)dt = f(x), \tag{12}$$

where $y''(x) = \varphi(t)$. We derive equation (12) by the method of successive approximations. For the kernel, we calculate using formulas (7)

Then the resolvent will be equal to the following

$$R(x,t,-1) = (x-t) - \frac{(x-t)^3}{3!} + \ldots + (-1)^{n-1}\frac{(x-t)^{2n-1}}{(2n-1)!} + \ldots .$$

This series is the expansion of the function $\sin z$ into a $(x-t)$-degree series. It defines the singular derivative of equations $R(x,t,-1) = \sin(x-t)$ and (12)

$$\varphi(x) = f(x) - \int_0^x \sin(x-t)f(t)dt. \tag{13}$$

Substituting equation (10) into (13), we find the solution of the original problem (11) using the singularity:

$$y(x) = \int_0^x (x-t)[f(t) - \int_0^t \sin(x-s)f(s)ds]dt = \int_0^x (x-t)f(t)dt - \int_0^x (x-t)\int_0^t \sin(x-s)f(s)dsdt. \tag{14}$$

(14) By rearranging the order of integration in the integral and calculating by internal integration,

$$\int_0^x (x-t)\int_0^t \sin(x-s)f(s)dsdt = \int_0^t f(s)ds\int_s^x (x-t)\sin(t-s)dt =$$

$$= \int_0^x [(x-s) - \sin(x-s)]f(s)ds. \tag{15}$$

Taking into account 14) we get from equation (15)

$$y(x) = \int_0^x \sin(x-t)f(t)dt. \tag{16}$$

Thus, (10) and (11) have a unique solution to the Cauchy problem, and this solution is defined by equation (16).

Often, the solution of the Volterra integral equation is reduced to the solution of the original problem for the differential equation, if the desired solution has the appropriate smoothness.

## Conclusion

This article presents a method for approximating ordinary linear differential equations by reducing them to Volterra's integral equation. Conversely, it is shown by examples that the derivation of Volterra's integral equation and the derivation of the Cauchy problem for linear differential equations are equivalent, and the derivation is shown to be correct by deriving it in the Maple program. The results of the work can be used to derive linear ordinary differential equations.

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# MOLECULAR BIOLOGY

## EFFECT OF THE MİCROBİOME ON THE PHARMACOLOGY OF CERTAİN DRUGS

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**Abstract**

The human microbiome comprises diverse and dynamic microbial communities inhabiting various body sites, including the skin, respiratory tract, and gastrointestinal tract. These microbial populations play a fundamental role in maintaining host homeostasis by modulating immune responses, metabolic processes, and neurophysiological functions. In recent years, growing evidence has highlighted the microbiome as an important factor influencing the pharmacokinetics and pharmacodynamics of many drugs. The microbiome can alter drug absorption, bioavailability, metabolism, and toxicity through direct biotransformation or indirect host-mediated mechanisms. The emerging field of pharmacomicrobiomics investigates how interindividual differences in microbiome composition contribute to variability in drug response, therapeutic outcomes, and adverse effects. In particular, the gut microbiome has been shown to affect the efficacy of antibiotics, anticancer agents, cardiovascular drugs, and psychotropic medications. Dysbiosis, or disruption of the normal microbial balance, is associated with numerous pathological conditions and may further modify drug response. This review article summarizes current knowledge on the role of the human microbiome in physiology, disease development, and drug–microbiome interactions, emphasizing its potential implications for personalized medicine and optimized pharmacotherapy.

**Keywords:** human microbiome, pharmacomicrobiomics, gut microbiome, drug–microbiome interaction, dysbiosis.

### Introduction

The human microbiome consists of microbial communities that inhabit various body sites and interact closely with the host organism. These communities exhibit site-specific stability and individuality and are strongly influenced by the host's physiological characteristics. Contemporary research has demonstrated the involvement of the microbiome in key physiological mechanisms, including immune responses, inflammatory processes, and aging [1].

A healthy microbiome is characterized by a diverse and balanced microbial community that resists the uncontrolled proliferation of pathogenic microorganisms. However, defining an optimal microbiome composition is complex across populations with different lifestyles, dietary patterns, and genetic backgrounds. Microbiome disruption (dysbiosis) is characterized by reduced microbial diversity, loss of core microbial components, or overgrowth of pathogenic species [2].

The microbiome begins to develop in the early stages of life and undergoes gradual changes until adulthood. The maternal microbiome and breast milk play a crucial role in shaping the newborn's microbiome as well as the development of the immune system. With changes in dietary patterns, the composition of the microbiome is remodeled and eventually attains a relatively stable structure in adulthood. Studies indicate that the adult human microbiome consists of stable core microorganisms and variable microbial populations that are sensitive to immune system modulation [3].

During the aging process, the microbiome influences immune, metabolic, and neurological functions and contributes to the diverse clinical manifestations of aging among individuals. Although diet, seasonal variations, geographical environment, and other ecological factors affect microbiome composition, individual-specific factors remain the primary determinants of microbiome diversity.

Pharmacomicrobiomics is a scientific field that investigates how intraindividual and interindividual differences in the microbiome influence responses to medications. Individual variability, as well as ecological factors such as seasonality, diet, chemical or biological exposures, and geographic location, play a significant role in shaping microbiome composition. The impact of human physiological processes on the composition and function of the microbiome is becoming increasingly evident. In parallel, understanding of the microbiome's role in both physiological and pathological processes continues to expand [4].

Notably, the microbiome can affect drug bioavailability, efficacy, and toxicity, and is therefore considered a promising target for pharmacological modulation. An integrative approach that combines clinical studies, modeling and simulation methods, and real-world data may help address current challenges and unlock the potential of pharmacomicrobiomics to improve the quality of healthcare delivery [5].

The largest microbial population in the human body resides in the gastrointestinal tract. The gut microbiome is directly involved in nutrition, metabolism,

immune responses, infections, and disease treatment, and has therefore been associated with the risk of both gastrointestinal and extraintestinal diseases. The gut microbiome is generally resilient to short-term perturbations and, due to its adaptability, can often return to a homeostatic state. Growing evidence links alterations in the microbiome to inflammatory bowel diseases, liver disorders, obesity, diabetes mellitus, and certain neurological conditions. However, establishing direct causal relationships or predicting disease development solely based on microbiome composition remains challenging [6].

In recent decades, microbiome research has primarily focused on assessing microbial composition and diversity using 16S rRNA analysis. Although most studies evaluate relative taxonomic abundance, absolute measures—such as total microbial load and gene expression levels—are often overlooked. Methods used to determine the absolute abundance of the gut microbiome include real-time polymerase chain reaction, the addition of synthetic DNA standards, and flow cytometry. Flow cytometry also enables discrimination between live and dead bacteria, thereby improving the accuracy of biological interpretation [7].

In addition, the functional plasticity of bacteria with the same taxonomic classification and similar genetic architecture should be considered. Such bacteria frequently exhibit different phenotypes, which may be associated with phase variation—programmed mechanisms that reversibly alter gene expression [8].

Since most drugs are administered orally and more than 70% of them exhibit low solubility, low permeability, or both, these compounds inevitably encounter microorganisms present at densities exceeding $10^8$ cells/mL in the small intestine and $10^{11}$ cells/mL in the colon. These microbial populations encode approximately 150 times more genes than the human genome, including a rich repertoire of enzymes. Therefore, the potential of the microbiome to influence drug pharmacology is exceptionally high [9].

According to the literature, more than 50 U.S. Food and Drug Administration (FDA)-approved drugs have clinically documented interactions with the gut microbiome. For example, bacterial tyrosine decarboxylases can convert levodopa—used in the treatment of Parkinson's disease—into dopamine at sites where absorption occurs; 5-aminosalicylate-based drugs, including sulfasalazine, are activated through microbiota-mediated azoreduction, with the released 5-aminosalicylic acid exerting a local therapeutic effect in the treatment of inflammatory bowel diseases; the topoisomerase I inhibitor irinotecan is excreted into the intestine as the glucuronidated metabolite SN-38G and can be reconverted into its cytotoxic form through bacterial β-glucuronidase–mediated removal of the glucuronide group; nitro-substituted benzodiazepines, including clonazepam, may be transformed into inactive 7-amino metabolites by bacterial nitroreductases [10;11].

Numerous findings demonstrate the role of the human microbiome in transplantation processes and its influence on the immune system, and a substantial body of scientific literature has been established on this topic. In transplantation settings, the importance of drug distribution within the body and the influence of the gut microbiome are becoming increasingly evident.

It is presumed that drug–microbiome interactions have always existed, but were often attributed to other factors or regarded as unexplained interindividual variability. These interactions are more likely to occur in patients receiving multiple medications, antimicrobial therapy, or treatment for comorbid conditions, placing transplant recipients at particular risk. Widely used drugs such as proton pump inhibitors, metformin, antibiotics, and laxatives are associated with more pronounced alterations in the microbiome and are frequently administered in transplant populations [12].

The rapid advancement of microbiome research has led to the introduction of new terminology that had not previously been used in the drug–interaction literature. Table 1 presents definitions of key terms commonly used in the microbiome field.

Table 1.

Glossary of commonly used terms in the drug–microbiome literature

| Term | Definition |
|---|---|
| **16S rRNA sequencing** | A method based on sequencing prokaryote-specific ribosomal RNA to determine bacterial diversity in a microbiome sample. Its ability to distinguish closely related species is limited. It is widely used due to its low cost and broad coverage. |
| **Alpha diversity** | A measure expressing species diversity and richness within a single sample. The Shannon index is one of the most commonly used metrics for assessing alpha diversity. Higher values indicate greater species diversity. |
| **Beta diversity** | A measure of differences in microbiome composition between distinct microbial communities. Bray–Curtis and UniFrac indices are commonly used. |
| **Dysbiosis** | A state characterized by alterations in taxonomic abundances within the microbiome that lead to functional disturbances and negatively affect human health. |
| **Metagenome** | The collective set of genes and genomes present in a microbiota, including bacteria, fungi, and viruses. It is identified through DNA extraction and sequencing. |

| | |
|---|---|
| **Microbial metabolites** | Small molecules produced as a result of microbial metabolism. Short-chain fatty acids formed during dietary fiber fermentation are among the most extensively studied. |
| **Microbial relative abundance** | The proportion of a specific bacterial species expressed as a percentage relative to the total bacterial count in a sample. |
| **Microbiome** | The entire collection of microorganisms present in a particular environment or habitat. |
| **Microbiota** | The microorganisms present in a defined environment (e.g., fecal or pulmonary environment), including bacteria, archaea, fungi, and viruses. |
| **Operational taxonomic units (OTUs) / Amplicon sequence variants (ASVs)** | Categories derived from grouping similar sequences that represent taxonomic units approximating species or strain level. |
| **Pharmacomicrobiome** | The influence of microbiome variability on drug absorption, distribution, metabolism, mechanisms of action, and toxicity. |
| **Sequencing depth (read depth)** | The number of sequences obtained per sample. Greater depth increases the likelihood of detecting low-abundance genomes. |
| **Shotgun sequencing** | A method based on untargeted whole-genome DNA sequencing, used to assess microbiome diversity and identify species. Its popularity is increasing as costs decline. |

This biotransformation, on the one hand, involves orally administered drug molecules prior to their absorption into the bloodstream and, on the other hand, applies to drugs or their metabolites excreted via the bile following hepatic processing. The bacterial transformation of xenobiotics primarily consists of hydrolytic and reductive reactions, which differ from hepatic metabolism where oxidative and conjugative reactions predominate. The metabolites formed as a result of these processes may be inactive, active, or even toxic [13].

In addition to hydrolytic reactions, the gut microbiota is also capable of performing the degradation of N-oxides, proteolysis, deconjugation, and other biochemical transformation reactions [14].

**Discussion.** The human microbiome is a complex and dynamic biological system that plays a crucial role in maintaining physiological homeostasis, regulating immune function, and optimizing metabolic processes. Advances in molecular and bioinformatic methodologies have clearly demonstrated that the microbiome is closely associated not only with health and disease but also with drug absorption, metabolism, efficacy, and toxicity. In particular, the gut microbiome, through its extensive enzymatic repertoire and high metabolic capacity, can directly influence the pharmacokinetic and pharmacodynamic properties of medications.

The scientific evidence presented in this article indicates that drug–microbiome interactions represent a significant source of interindividual variability in drug response. Differences in the clinical effects of the same medication among patients are strongly linked to the taxonomic composition, functional potential, and metabolic activity of the microbiome. By elucidating the scientific basis of this variability, pharmacomicrobiomics offers new opportunities for the development of personalized therapeutic strategies.

Dysbiosis of the gut microbiome has been associated with the development of inflammatory, metabolic, neurological, and oncological diseases, and may contribute to reduced drug efficacy or increased risk of adverse toxic effects. Widely used medications such as antibiotics, proton pump inhibitors, metformin, and immunosuppressive agents can substantially alter microbiome structure. These effects are of particular clinical relevance in transplant recipients and individuals with comorbid conditions [14].

Although methods used in microbiome research—including 16S rRNA sequencing, real-time PCR, flow cytometry, and shotgun metagenomics—provide valuable insights, the assessment of functional characteristics and absolute microbial abundance remains a key priority for future studies. Furthermore, the functional plasticity and phase variation of bacteria with similar taxonomic identities should be carefully considered when interpreting microbiome data [9;15].

In conclusion, a deeper understanding of the microbiome's influence on drug pharmacology holds great potential for improving treatment efficacy, enhancing drug safety, and advancing personalized therapeutic approaches in clinical practice. Large-scale, multicenter, and longitudinal studies in pharmacomicrobiomics may enable the future integration of microbiome-based diagnostic and therapeutic strategies into healthcare systems. This approach will play an important role in strengthening the scientific foundations of personalized medicine, one of the central directions of modern healthcare.

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# MOLECULAR PHYSIOLOGY AND GENETICS

## BIOCHEMICAL MARKERS OF ASBESTOS-RELATED DISEASES IN WORKERS (LITERATURE REVIEW)

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**Abstract**

**Introduction.** The article reflects the impact of asbestos on human health due to the widespread use of asbestos-containing materials in the past in industrial and residential construction.

**The aim of the study** is to provide an analytical overview of the current state of biological markers of asbestos-related diseases, to show the risks of asbestos exposure to human health in production conditions, and to present current validated markers of mesothelioma and asbestosis.

**Materials and methods.** The study is based on an analysis of Ukrainian and foreign publications on the implementation of biological markers for the early detection of asbestos-related diseases in workers and the prospects for the use of new validated approaches and biological media for the early detection of mesothelioma and asbestosis.

**Research results.** The search for biomarkers is actively developing, as evidenced by the discovery of a number of promising candidates that could complement or replace SMRP. These include osteopontin, fibulin-3, HMGB1, and microRNA. This indicates a trend towards the creation of combined multi-marker panels that would increase the sensitivity and specificity of diagnosis and also have additional prognostic value, which is critical for the early detection of most cases of mesothelioma.

**Conclusions.** A review of the literature showed that the field of biochemical markers for asbestosis and mesothelioma is being actively studied and developed, especially in the context of the search for mesothelioma biomarkers. Although no single marker currently provides ideal diagnostic accuracy for both diseases, some require validation, but several are quite promising.

**Keywords:** asbestos, occupational exposure, biochemical markers. asbestos, mesothelioma.

### Introduction

Elimination of asbestos-related diseases: WHO calls on all countries to completely ban the use of asbestos and to implement effective mechanisms for removing asbestos already present in buildings as part of national public health programmes. Today, there's a regulation in EU countries (Directive 2009/148/EC, amended by 2023/2668) that sets strict measures to minimise asbestos exposure during demolition, maintenance, or repair of buildings that contain asbestos. The current MPC in the air of the working area has been reduced tenfold: from 0.1 fibres/cm³ to 0.01 fibres/cm³ (average value for an 8-hour working day). The deadline for Member States to implement this new limit is 21 December 2025. A further reduction in the limit is planned by 21 December 2029 to 0.002 fibres/cm³ (if fine fibres are not measured) or maintenance at 0.01 fibres/cm³ (if all fibres are measured using electron microscopy).

An international scientific assessment of the impact of all types of asbestos on human health, conducted by the IARC and WHO, did not identify a threshold level below which asbestos exposure is safe and poses no risk to human health (no threshold for carcinogenicity).

However, despite bans in many developed countries, significant global exposure persists through mining, manufacturing and environmental contamination, putting millions of people at risk [1]. The World Health Organisation (WHO) estimates that more than 100,000 deaths per year are related to asbestos [2].

The results of epidemiological studies show that there is a large amount of data obtained in different countries on the link between occupational exposure to asbestos and its mixtures (when inhaled into the human body) and the risk of developing asbestosis, pleural plaques, cancer of the larynx, bronchi, and lungs, ovarian cancer, and malignant mesothelioma (parietal pleura, peritoneum, pericardium). Most ASDs are fatal, and most ASDs are caused by asbestos in the lungs [1-5]. The International Agency for Research on Cancer (IARC) classifies asbestos as a known human carcinogen, also associated with lung, laryngeal, and ovarian cancer [3].

When asbestos fibres enter the respiratory tract, they settle in the lungs, causing a cascade of adverse effects, including the formation of reactive oxygen species (ROS), chromosome damage, mitotic disorders, gene mutations, and changes in growth factor signalling and apoptosis. These processes contribute to both fibrosis and carcinogenesis [4].

Given the long latency period characteristic of asbestos-related diseases, there is an urgent need for reliable early detection strategies. Biochemical markers that can be measured in readily available biological samples offer a potential avenue for identifying individuals at increased risk or detecting disease at a preclinical stage, thereby improving the prospects for effective treatment.

**Research objective**. The objective of this study is to analyse the current state of implementation and search for new biochemical markers for early detection of asbestos-related diseases in workers

**Materials and methods**. Analysis of specialized and scientific-methodological literature.

**Object and methods of research.**

The results of epidemiological studies show that there is a large amount of data obtained in different countries on the link between occupational exposure to asbestos and its mixtures (when inhaled into the human body) and the risk of developing asbestosis, pleural plaques, cancer of the larynx, bronchi and lungs, ovarian cancer, and malignant mesothelioma (of the parietal pleura, peritoneum, and pericardium [1-3].

According to a number of researchers, the carcinogenic hazard of asbestos is not uniform and is determined by its type (chemical composition). A number of authors consider chrysotile asbestos to be the least hazardous to humans, which makes it possible to use it in industry with minimal risk to workers' health [2-8, 10-14]. The problem with identifying specific markers for asbestosis is that asbestos fibres themselves are not present in readily accessible biological fluids such as blood or urine; they are mainly localised in lung tissue [ 9-15]. Direct assessment of exposure often requires invasive procedures such as bronchoalveolar lavage (BAL). Therefore, research focuses on identifying 'response markers' that reflect changes in biological function caused by asbestos exposure, rather than the direct presence of fibres. These responses cover a spectrum of molecular changes, from oxidative stress to immune system activation.

Unlike mesothelioma, where the tumour itself produces specific molecules that can serve as markers, asbestosis is characterised by a non-tumour process of pulmonary fibrosis. This difference makes it difficult to identify markers with high specificity for asbestosis compared to other forms of pulmonary fibrosis or inflammatory conditions [9-13].

Asbestos exposure is a known inducer of oxidative stress in the lungs, leading to the formation of reactive oxygen species (ROS) that contribute to cell damage and fibrosis development.

In the context of asbestos exposure, several markers of oxidative stress have been investigated, including 8-hydroxy-2'-deoxyguanosine (8-oxo-dGuo) and 8-iso-isoprostane PGF2α (8-iso-PGF2α). Elevated levels of 8-oxo-dGuo, a DNA adduct, in urine were associated with asbestos exposure [6]. Studies show that individuals with a history of asbestos exposure often exhibit higher levels of 8-OHdG in their biological samples. This suggests that 8-OHdG could potentially serve as a marker of exposure or early biological effect.

Although elevated levels of oxidative stress markers such as 8-OHdG indicate cell damage consistent with asbestos exposure, their diagnostic value for established asbestosis is limited by insufficient specificity. Elevated oxidative stress is a common feature of many lung diseases and even normal ageing, making it difficult to distinguish asbestosis from other conditions based on these markers alone.

There is evidence that asbestos exposure causes the release of hypermobile protein box 1 (HMGB1), a nuclear protein that is a powerful driver of chronic inflammatory processes leading to both fibrosis (characteristic of asbestosis) and carcinogenesis (relevant for mesothelioma and lung cancer) [7].

Studies have shown that individuals exposed to asbestos tend to have higher levels of HMGB1. In addition, increased levels of unacetylated HMGB1 in blood serum have been proposed as a potential biomarker of response to asbestos exposure [8].

HMGB1 appears to play a central role in the pathogenesis of asbestos-related diseases, including asbestosis. Although its elevated levels may indicate asbestos exposure and the presence of an inflammatory response that promotes fibrosis, HMGB1 is not specific to asbestosis and is also involved in the development of mesothelioma and other inflammatory conditions. Therefore, it may serve as a marker of exposure and potential risk rather than a definitive diagnostic marker for asbestosis.

Other potential markers include fibronectin and glycoprotein. It has been studied as a potential biomarker in individuals exposed to asbestos [6]. Its role in the fibrotic process in asbestosis makes it a logical candidate, but its specificity remains an issue, as it is involved in fibrosis of various origins and therefore requires further study of its role as a biomarker.

Several inflammatory cytokines, such as interleukin 6 (IL-6) and interleukin 8 (IL-8), which play a key role in immune responses and inflammation, have been investigated as potential biomarkers of the body's response to asbestos exposure. Similarly, the chemokine RANTES (CCL5) has also been studied [6]. These markers reflect the inflammatory component of asbestosis, but are not specific to this disease. Mineralogical analysis of bronchoalveolar lavage (BAL) fluid is a more direct method of assessing asbestos exposure by measuring the number and type of asbestos bodies and fibres present in the lavage fluid. This analysis can detect higher concentrations of fibres in patients with asbestosis [8] Although it is considered a reliable biomarker of past exposure and pulmonary burden, BAL is an invasive procedure requiring bronchoscopy and specialised laboratory expertise, limiting its routine use as a primary diagnostic tool [2].

Although biochemical markers can provide valuable information about the biological response to asbestos exposure, they currently play a more supportive role in the diagnosis of asbestosis. They can help identify individuals with significant exposure or understand the underlying pathological processes, but they are not yet sensitive or specific enough to serve as primary diagnostic criteria in most cases [6].

The established biochemical markers for mesothelioma are as follows:

Soluble mesothelin-related peptides (SMRP): Soluble mesothelin-related peptides (SMRP) are the most widely studied and only blood biomarker approved by the Food and Drug Administration (FDA) for mesothelioma. Mesothelin, a precursor protein with a molecular weight of 71 kDa, is physiologically cleaved into two

mature proteins: N-terminal megakaryocyte-potentiating factor (MPF) with a molecular weight of 31 kDa, secreted into the blood, and C-terminal glycosylated phosphatidylinositol-linked glycoprotein with a molecular weight of 40 kDa, which is bound to the plasma membrane. SMRP is released into the blood after further processing of the membrane-bound protein [8,13]. Serum SMRP levels are significantly elevated in patients with malignant mesothelioma compared to healthy individuals, individuals exposed to asbestos without mesothelioma, and individuals with benign asbestos-related diseases [13]. According to studies, the sensitivity of SMRP in the diagnosis of mesothelioma varies widely, from approximately 32% to 84%, while specificity is typically between 72% and 96%, depending on the control groups and thresholds used [8,15]. Sensitivity tends to be lower in the early stages of the disease and in non-epithelioid histological subtypes. SMRP plays a crucial role in monitoring patients diagnosed with epithelioid or biphasic mesothelioma for disease progression, response to treatment, and recurrence [8]. Elevated SMRP levels may indicate disease progression, while decreased levels may indicate response to therapy [15,16].

Other promising markers:

Osteopontin (OPN), an integrin-binding protein involved in various biological processes, including tumorigenesis, progression, and metastasis, is often found at elevated levels in the serum and plasma of patients with mesothelioma [6].

According to studies, the diagnostic sensitivity of OPN is approximately 65-78%, and specificity is approximately 81-86% in distinguishing mesothelioma from individuals exposed to asbestos [8]. However, its specificity tends to be lower when compared to benign pleural effusions or other diseases other than mesothelioma [16-19].

Several studies suggest that high OPN levels are associated with poor prognosis in patients with mesothelioma, indicating its potential as a prognostic marker [4,8].

Meta-analyses and comparative studies suggest that plasma OPN may demonstrate higher diagnostic accuracy compared to serum OPN, possibly due to thrombin degradation in peripheral blood [8,19].

Fibulin-3, an extracellular glycoprotein involved in the regulation of cell proliferation and migration, is another promising biomarker for mesothelioma, with elevated levels found in the blood and pleural effusions of patients [6].

Initial studies reported high diagnostic sensitivity (up to 90-97%) and specificity (approximately 95%) of fibulin-3 in blood plasma in distinguishing mesothelioma from individuals exposed to asbestos. However, subsequent validation studies have shown more heterogeneous results, with sensitivity ranging from 12.7% to 87% and specificity from 66% to 89% [9].

Fibulin-3 in pleural fluid has shown potential as a prognostic factor, with lower levels associated with longer survival in some studies [8]. High blood levels, on the other hand, may indicate a poorer prognosis [4,8].

High mobility group box 1 (HMGB1), a protein released during cell necrosis and involved in inflammation, is found at elevated levels in the serum of patients with mesothelioma [6].

Studies have shown that serum HMGB1 levels can reliably distinguish between patients with mesothelioma, individuals exposed to asbestos, and healthy control subjects. Notably, the hyperacetylated isoform of HMGB1 has demonstrated particularly high sensitivity (100%) and specificity (100%) in differentiating mesothelioma from individuals exposed to asbestos and healthy control subjects in some studies, outperforming other proposed biomarkers [9].

High HMGB1 levels are associated with poor prognosis in mesothelioma [6,9]

MicroRNAs (miRNAs), small non-coding RNA molecules that regulate gene expression, have shown altered expression patterns in patients with mesothelioma and individuals exposed to asbestos [4,14, 22]. A meta-analysis identified circulating miRNAs such as miR-126, miR-132-3p, and miR-103a-3p as promising diagnostic biomarkers for mesothelioma, with combined areas under the curve (AUC) indicating good diagnostic accuracy. Combining miRNAs with other markers, such as mesothelin, may further enhance diagnostic potential [9,10]. Certain miRNAs, such as miR-197-3p, have also been associated with prognosis in mesothelioma [8,15].

Immunohistochemical markers (tissue biopsy):

Although they are not biochemical markers in the traditional sense (soluble markers in fluids), immunohistochemical (IHC) markers play a crucial role in confirming the diagnosis of mesothelioma from tissue biopsies obtained through invasive procedures [9,16].

Calretinin: A highly sensitive mesothelial marker, positive in 80-100% of epithelioid mesotheliomas, but with lower sensitivity in sarcomatoid types (50-60%). It does not have ideal specificity, as it can be expressed in other malignant neoplasms [16].

Cytokeratin 5/6: Another widely used mesothelial marker with good sensitivity (51-100%) for epithelioid mesothelioma, but lower for sarcomatoid (13-29%). It can also be expressed in some squamous cell carcinomas [16]

WT1: A nuclear marker with reported sensitivity in the range of 70-100% for establishing the mesothelial lineage in epithelioid mesothelioma, but lower in sarcomatoid (10-45%). It may also be positive in some other carcinomas [16].

Podoplanin (D2-40): A membrane marker with high sensitivity (80-100%) for epithelioid mesothelioma. It is also a marker for lymphatic endothelium [16].

These and other IHC markers, including epithelial markers such as CEA and MOC-31, are commonly used in combination as an immunopanel to improve diagnostic accuracy and to differentiate mesothelioma from metastatic carcinomas and other pleural lesions [8].

Distinguishing between asbestosis and mesothelioma using biochemical markers:

Scientific reviews focus primarily on markers for detecting the effects of asbestos/asbestosis in general or specifically for mesothelioma [2-5]. Less attention is

paid to biochemical markers that would directly and definitively distinguish between established asbestosis and mesothelioma in individuals with a history of asbestos exposure. Some markers, such as HMGB1, are elevated in both conditions due to their common aetiology – asbestos exposure and involvement of inflammatory pathways. HMGB1 levels may be higher in mesothelioma in some cases, but this alone may not be sufficient for clear differentiation.

Soluble mesothelin-related peptides (SMRP) are generally considered to be more specific for mesothelioma and are not usually significantly elevated in isolated asbestosis [8]. Therefore, high SMRP levels in an individual exposed to asbestos and presenting with respiratory symptoms would raise suspicion of mesothelioma rather than asbestosis [13,17].

Osteopontin levels may be elevated in patients with asbestosis (especially those with pleural plaques and fibrosis) as well as in mesothelioma [16-21]. The degree of elevation may vary, with higher levels often seen in mesothelioma, but overlap is likely, limiting its use as a single marker for differentiation.

**Prognostic and monitoring biochemical markers of mesothelioma:**

Serum SMRP levels have shown potential in monitoring response to treatment and prognosis in mesothelioma, with decreased levels potentially indicating improved survival. Higher baseline SMRP levels have been associated with poorer survival in some studies [8,22].

Osteopontin has also shown potential as a prognostic marker in mesothelioma. Several studies have reported that higher baseline serum or plasma osteopontin levels are associated with shorter overall survival [4, 8, 23].

Interestingly, fibrillin-3 levels in pleural fluid have been identified as an independent significant prognostic factor for survival in patients with mesothelioma, with lower levels correlating with longer survival [8]. High blood fibrillin-3 levels, on the other hand, may indicate a worse prognosis [4].

High levels of HMGB1 have been associated with poor prognosis in mesothelioma [4,8].

Certain microRNAs, such as miR-197-3p, have been associated with increased survival time in patients with mesothelioma, suggesting their potential as prognostic biomarkers [24, 25].

Longitudinal monitoring of SMRP levels and possibly other markers, such as osteopontin and fibulin-3, may provide valuable information for assessing tumour response to therapy and detecting disease progression or recurrence over time [8,28].

Table

Biochemical markers for the diagnosis of asbestosis and mesothelioma.

| Marker | Sample type | Main clinical application | Sensitivity range (%) | Specificity range (%) | Main restrictions |
|---|---|---|---|---|---|
| Soluble mesothelin-related peptides (SMRP) | Serum, pleural fluid | Monitoring (Meso), Diagnostics (Mesotherapy) | 32-84 | 72-96 | Lower sensitivity in early stages and in non-epithelial mesothelioma |
| Osteopontin (OPN) | Serum, plasma | Diagnostics (Mesotherapy) Prognosis (Meso) | 65-78 | 81-86 | Lower specificity compared to benign pleural effusions and other diseases |
| Fibulin-3 | plasma, Serum, pleural fluid | Diagnostics (Mesotherapy) Prognosis (Meso) | 12.7-97 | 66-95 | The sensitivity of the test in different studies requires further validation. |
| HMGB1 | Serum | Diagnostics (Mesotherapy), Exposure (Asb) | 72-100 | 80-100 | Requires further validation, especially for the hyperacetylated isoform |
| microRNA (miRNAs) | Serum, plasma, Biological Tissue | Diagnostics (Mesotherapy) , Prognosis (Meso) | Various | Various | Research is ongoing, requires validation as multimarker signatures |
| Mineralogical analysis (BAL) | BAL | Exposure (Asb), Asbestos Lung Burden | - | - | Invasive procedure |
| Calretinin (IGC) | Biological Tissue | Diagnostics (Mesotherapy) | 50-100 | 60-98 | Lower sensitivity in sarcomatoid mesothelioma, expressed |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | in other cancers |
| Podoplanin (D2-40) (IGC) | Biological Tissue | Diagnostics (Mesotherapy) | 80-100 | High | Also stains lymphatic endothelium |
| ATG5 | Blood | Diagnostics (Mesotherapy) | High | High | The information is preliminary and needs to be validated. |
| FLNA, FBLN1, TSP-1 (Proteomics) | Serum | Diagnostics (Mesotherapy) | High | High | New markers requiring validation |

Note: Asb = Asbestos, Meso = Mesothelioma, IHC = Immunohistochemistry, BAL = Bronchoalveolar lavage. Sensitivity and specificity ranges are approximate and based on reviewed specimens.

Validation studies have identified filamin A (FLNA), fibulin 1 (FBLN1) and thrombospondin-1 (TSP-1) as promising diagnostic candidates that demonstrated high diagnostic value both individually and in combination for distinguishing mesothelioma from healthy control subjects, asbestos-exposed individuals, and patients with pleural plaques or asbestosis [29].

Autophagy-related protein 5 (ATG5), a factor involved in autophagy, has emerged as a new potential biomarker for the early detection of malignant pleural mesothelioma [27].

A study evaluating ATG5 levels in asbestos-exposed individuals, mesothelioma patients, and healthy control subjects found that ATG5 was most effective at distinguishing between asbestos-exposed individuals with and without mesothelioma.

Notably, ATG5 showed promise in detecting mesothelioma with high sensitivity and specificity in prediagnostic samples collected two years prior to clinical diagnosis [27].

Although miR-126 and mesothelin were identified as significant prognostic biomarkers in the same study, ATG5 stood out for its potential for early diagnosis [27].

Recent advances in proteomic technologies, such as analyses based on slowly dissociating modified aptamers (SOMAmer) and isobaric tags for relative and absolute quantification (iTRAQ) combined with liquid chromatography-tandem mass spectrometry (LC-MS/MS), have facilitated the discovery of new panels of mesothelioma protein biomarkers [29].

Proteomic analysis based on SOMAmer identified a panel of 13 protein biomarkers that demonstrated high accuracy (approximately 92-99%) in detecting malignant mesothelioma in individuals exposed to asbestos, even detecting a significant proportion of the disease in its early (I/II) stages [28-30]. This panel included both inflammatory and proliferative proteins associated with asbestos-induced malignancies [31-34].

Using iTRAQ in combination with 2D-PLC-MS/MS, researchers identified 145 differentially expressed serum proteins between mesothelioma patients and healthy control subjects [29].

Further research into identifying specific biochemical markers that can effectively differentiate between asbestosis and mesothelioma, especially in individuals with a history of asbestos exposure who have respiratory symptoms, is warranted. A deeper understanding of the molecular mechanisms underlying the development of asbestosis and mesothelioma is likely to lead to the discovery of additional new biomarkers and potential therapeutic targets.

**Conclusions**

1. A review of the literature showed that the field of biochemical markers for asbestosis and mesothelioma is being actively studied and developed, especially in the context of the search for mesothelioma biomarkers. Although no single marker currently provides ideal diagnostic accuracy for both diseases, some require validation, but several are quite promising.
2. Despite significant progress in the study of biomarkers for asbestos-related diseases, soluble mesothelin-related peptides (SMRP) remain the most established and only FDA-approved biomarker for monitoring mesothelioma.
3. The search for biomarkers is actively developing, as evidenced by the discovery of a number of promising candidates that could complement or replace SMRP. These include osteopontin, fibulin-3, HMGB1, and microRNA. This indicates a trend towards the creation of combined multi-marker panels that would increase the sensitivity and specificity of diagnosis and also have additional prognostic value, which is critical for the early detection of most cases of mesothelioma.
4. The analysis clearly shows a disproportion in the volume of research: the main focus is on mesothelioma. Research into specific biochemical markers of asbestosis itself is less extensive. Efforts in this direction are currently concentrated on indirect indicators, such as markers of asbestos exposure and markers of secondary processes — oxidative stress and fibrosis (e.g., HMGB1), which indicates an urgent need to discover more specific biomarkers for the early diagnosis of asbestosis itself.

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# NEUROBIOLOGY

## THE IMPACT OF MILD ANEMIA ON COGNITIVE FUNCTIONS OF ELDERLY PATIENTS WITH COGNITIVE IMPAIRMENT OR DEMENTIA OF VASCULAR OR ALZHEIMER'S DISEASE ORIGIN

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**Abstract**

Anemia is frequent in elderly with cognitive decline. The aim of our study was to examine the association between anemia and cognitive functioning among elderly patients with AD, VD and mixed AD and VD (mixed dementia, MD).

Material and methods: We examined 38 cognitive impaired patients with mild anemia (80.0±6.76 years old, 14 males and 24 females, 11 with AD, 12 with VD and 15 with MD) and 108 cognitive impaired patients without anemia (75.55±7.39 years old, 34 males and 74 females, 27 with AD, 44 with VD and 24 with MD) with the following neuropsychological battery Mini Mental State Examination (MMSE), Isaac's Set Test (IST), Literal fluency Test (LFT), Clock Drawing Test (CDT), 10 Words Test, Digit Symbol Substitution test (DSST 90sec), Digit Span Test (DST forward and backward) twice over a period of 2 years. All results were interpreted at 95% confidential level.

Results: Patients with anemia showed lower MMSE, IST, LFT, CDT and DSST test results vs those without. There were correlations between serum hemoglobin level and MMSE (reciprocal), IST (reciprocal), LFT (linear), CDT (sqr. root), DSST (sqr. root or linear) test performances.

Conclusions: Anemia is frequent in elderly patients with cognitive deficits and dementia. The existence of anemia is associated with additional executive dysfunction in such patients.

**Keywords:** anemia, cognitive impairment, elderly, executive functions.

The frequency of anemia among elderly is about 35%. It is even more frequent among those over 80 years of age, patients with diabetes mellitus, with gate impairments, visual problems or dependent from caregivers (Krishnapillai, 2015). Anemia, itself, is associated with cognitive impairments and dementia (Choi, 2020; Gattas, 2020; Weiss, 2022; Fehsel, 2023). Possible causative relation s found between anemia and serum iron deficiency and development of Alzheimer's disease (AD), although the exact mechanism is unclear (Andreev, 2020; Gattas 2020; Lei, 2021; Fehsel, 2023). Anemia is a risk factor for development of brain vascular disease (VD) and worsening of small vessels disease (Wolters, 2019; Fonseca, 2021).

The aim of our study was to examine the association between anemia and cognitive functioning among elderly patients with AD, VD and mixed AD and VD (mixed dementia, MD).

Material and methods

We examined 38 cognitive impaired patients with mild anemia (80.0±6.76 years old, 14 males and 24 females, 11 with AD, 12 with VD and 15 with MD) and 108 cognitive impaired patients without anemia (75.55±7.39 years old, 34 males and 74 females, 27 with AD, 44 with VD and 24 with MD).

The inclusion criteria of the study were 1. Age ≥ 60 years; 2. Confirmed by neuropsychologist cognitive impairment at ≥2 cognitive domains; 3. Confirmed on the basis of history, neurological and somatic examination, laboratory data and imaging study diagnosis of AD or SVD or MD; 4. HB level above 100g/l; 5. No active oncologic disease; 6. Lack of other neurological diseases such as trauma, brain tumors, neuroinfections, demyelinating diseases or epilepsy; 7. Lack of decompensation of coexisted somatic diseases during the study; 8. Lack of psychiatric diseases, except of mild depression or anxiety; 9. Lack of treatment or usage of benzodiazepines, modafinile acetate, hallucinogens and other psychoactive drugs, except for low dosages of Quetiapine (≤50mg/d), Pregabaline (≤150mg/d), Gabaneural (≤600mg/d), Hydroxyzine (≤25mg/d) or antidepressants; 10. Lack of alcohol abuse or usage of forbidden substances; 11. Signed informed consent.

After clinical interview and confirmation of the diagnosis, the patients were examined via the following neuropsychological battery: Mini Mental State Examination (MMSE), Isaac's Set Test (IST for verbal fluency), Literal fluency Test (LFT; variant M-O-H-A in Bulgarian, 1 minute for every letter), Clock Drawing Test (CDT), 10 Words Test (for working memory, delayed recall and recognition (10/20words), Bulgarian variant), Digit Symbol Substitution test (DSST 90sec), Digit Span Test (DST forward and backward) and 21 Hamilton Depression Scale (HDS). All patients with HDS above 12 points were excluded.

The same neuropsychological battery was used 2 years after the first examination.

The statistical analysis was done via parametric and non-parametric tests as ANOVA, MANOVA, Man-Whitney and Kruskal-Wallis test statistics and simple regression analysis via SPSS 20.0 and Statgraphics 20.0. All results were interpreted at 95% confidential level (p 0.05).

Results:

1. Demographic data

Patients with anemia were slightly more elderly than those without (see table 1). Although females prevailed over males at both groups, the frequency of anemia among male patients with cognitive decline was higher. Interestingly, patients with anemia were slightly better educated than those without.

2. Correlation between anemia and cognitive functioning.

Patients with anemia showed lower MMSE, IST, LFT, CDT and DSST test results vs those without (see table 2). They also showed addition 2 years' delay on IST and DSST. We didn't find correlations between anemia and DST or memory (10WT).

3. Correlation between serum hemoglobin level and cognitive performances.

There were correlations between serum hemoglobin level and MMSE (reciprocal), IST (reciprocal), LFT (linear), CDT (sqr. root), DSST (sqr. root or linear) test performances (see table 3). We failed to find any correlations between serum hemoglobin level and DST or 10WT. We didn't find correlations between serum hemoglobin level and 2 years' delay on any examined scale.

Discussion:

The prevalence of mild anemia among our patients was 26%. It was more often in our male patients (29%) vs females (24%). It could be due to socio-economic purposes and our restrictive criteria (we excluded patients with moderate to severe dementia). However, our patients with anemia were slightly more elderly than those without and at such age prevailed females, which principally had better diet intake and better medical and social care than males in our country. Interestingly, anemia was more frequent in our high (26.5%) and middle (27.45%) educated patients than those with basic education (16.67%). This fact can be explained by our specific socio-economic factors such as living conditions (patients with basic education most often live in small villages and eat healthier food, that grow alone, which included meat and highly educated live in bigger towns and cities and depend on food supply from shops and commercial centers), sick patients with basic education have higher mortality rate (because of lack of sufficient medical care and delayed diagnosis), etc.

Our patients with anemia have lower global cognition, lower results on test for executive functioning (IST, LFT, DSST) and visual-special abilities than those without. The serum hemoglobin level also correlates with above mentioned scales. Although there aren't correlations with memory itself. Such results are obtained from other authors (Gattas, 2020; Weiss, 2022; Fehsel, 2023). Anemia-associated cognitive impairments are comparatively mild and are significantly associated with the serum hemoglobin level, but not so much with the exact level of serum iron (Agrawal, 2019; Gattas, 2020). Multiple mechanisms of impact of anemia on cognitive dysfunction are suggested. The significant role might play the low hemoglobin level, Vitamin B12 deficiency and the other comorbidities (Gattas, 2020; Lei, 2021; Fehsel, 2023). One of the possible mechanism of impact is the mechanism of hypoxemia and lowering of blood flow into the brain which induces chronic inflammation, ischemia and oxidative stress with impaired amyloid clearance and worsening of small vessels' disease (Wolters, 2019; Gattas, 2020; Fonseca, 2021; Lei, 2021; Fehsel, 2023). Another potential mechanism of brain damage is associated with the level of erythropoietin and its receptors throughout the brain. Erythropoietin and its receptors play important protective role against neurodegeneration (Gattas, 2020). Low iron level is also associated with amyloid deposition and neurodegeneration at some specific conditions (Fehsel, 2023). Because of the vulnerability of deep white matter to hypoxia, the most impaired cognitive domain in cases with anemia is executive functioning, which is mostly associated with frontal and deep white matter dysfunctions (Andreev, 2020; Choi, 2020; Gattas, 2020; Weiss, 2022; Fehsel, 2023). We also find correlations mostly between executive functions and anemia (information processing speed and attention, but not cognitive inhibition and working memory). Interestingly, we failed to find any correlations between short term and long term memory (including retrieval from memory depos and recognition) and anemia which suggested partial preservation of temporal lobe functioning at least for short – periods of time. We also obtain additional visual-spatial disability in association with anemia, which also could be explained with deep white matter dysfunction but at most posterior brain regions (e.g. occipital and parietal lobes).

Conclusions: Anemia is frequent in elderly patients with cognitive deficits and dementia. The existence of anemia is associated with additional executive dysfunction in such patients.

Table 1

Demographic and clinical data

| | AD | VD | MD | Total | Age (years) | M:F | B:M:H | Hb (g/l) |
|---|---|---|---|---|---|---|---|---|
| Without anemia | 27 | 44 | 27 | 108 | 75.55±7.39 | 34:74 | 10:61:37 | 136.66±12.79 |
| With anemia | 11 | 12 | 15 | 38 | 80.0±6.76 | 14:24 | 2:22:14 | 115.21±4.21 |
| P | | | | | 0.0014 | 0.0022 | 0.0349 | 0.0001 |
| Total | 38 | 56 | 52 | 146 | 76.71±7.47 | 48:98 | 12:83:51 | 130.12±17.05 |
| Legend: AD – Alzheimer's disease; VD – vascular dementia, MD – mixed dementia; M:F – male:female ratio; B:M:H – with basic: with middle: with high education. | | | | | | | | |

Table 2

Correlations between anemia and cognitive performances of our patients with cognitive impairment and dementia.

| The correlations between anemia and: | Average or mediana of patients without and with anemia | p= |
|---|---|---|
| MMSE 1 (p.) | NA | >0.05 |
| MMSE 2 (p.) | 25 vs 22 | 0.0232* |
| 2 years MMSE delay (p.) | NA | >0.05 |
| IST1 (p.) | NA | >0.05 |
| IST2 (p.) | 30 vs 26 | 0.0311* |
| 2 years IST delay (p.) | -1.0 vs -3.0 | 0.0162* |
| LFT 1 (p.) | NA | >0.05 |
| LFT 2 (p.) | 21.04±10.98vs 15.44±10.06 | 0.0091 |
| 2 years LFT delay (p.) | NA | >0.05 |
| CDT 1 (errors) | 0.0 vs 1.0 | 0.0025* |
| CDT 2 (errors) | 1.0 vs 3.0 | 0.0127* |
| 2 years increasing of the number of errors on CDT. | NA | >0.05 |
| DSST 1 (p.) | 29.61±13.32 vs 24.29±13.01 | 0.0430 |
| DSST 2 (p.) | 25.96±14.57 vs 19.03±13.83 | 0.0156 |
| 2 years DSST delay (p.) | -2.0 vs -3.5 | 0.0485* |
| Legend: MMSE – Mini Mental State Examination; IST – Isaac's Set Tes,; LFT – Literal Fluency Test; CDT – Clock Drawing Test; DSST – Digit Symbol Substitution Test; 1- at first examination; 2 – 2 years after the first examination; * Kruskal-Wallis. Without * t-test. We excluded all scales without correlation with anemia. | | |

Table 3

Regression analysis – the correlation between serum hemoglobin level and cognitive performances.

| Regression analysis between the serum Hemoglobin level (g/l; X) on neuropsychological scales (Y): | rr | Model of correlation, p= |
|---|---|---|
| MMSE 1 (p.) | -0.20 | reciprocal (X), p=0.0177 |
| MMSE 2 (p.) | -0.22 | reciprocal(X), p=0.0061 |
| 2 years MMSE delay (p.) | NA | >0.05 |
| IST1 (p.) | NA | >0.05 |
| IST2 (p.) | -0.20 | reciprocal (X), p=0.0224 |
| 2 years IST delay (p.) | NA | >0.05 |
| LFT 1 (p.) | 0,25 | linear, p=0.0050 |
| LFT 2 (p.) | 0,34 | linear, p=0.0001 |
| 2 years LFT delay (p.) | NA | >0.05 |
| CDT 1 (errors) | -0.23 | Sqr root (У), p=0.0075 |
| CDT 2 (errors) | -0.21 | Sqr root (У), p=0,0138 |
| 2 years increasing of the number of errors on CDT. | NA | p>0.05 |
| DSST 1 (p.) | 0.21 | Sqr root (X), p=0.0168 |
| DSST 2 (p.) | 0.26 | linear, p=0.0032 |
| 2 years DSST delay (p.) | NA | >0.05 |
| Legend: MMSE – Mini Mental State Examination; IST – Isaac's Set Tes,; LFT – Literal Fluency Test; CDT – Clock Drawing Test; DSST – Digit Symbol Substitution Test; 1- at first examination; 2 – 2 years after the first examination; rr – correlation coefficient | | |

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# CHRONIC OBSTRUCTIVE PULMONARY DISEASE AND COGNITIVE IMPAIRMENTS OF VASCULAR AND ALZHEIMER'S ORIGIN

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**Abstract**

Chronic obstructive pulmonary disease (COPD) is frequent among elderly patients with dementia. The aim of our study was to examine cognitive functions of patients with COPD in cases with Alzheimer's disease (AD), vascular dementia (VD) and mixed dementia (MD) and to compare them to those without COPD.

Material and methods: We examined 48 patients with mild COPD (on average 77.43±7.87 years old; 21 males, 27 females, 8 with AD, 15 with VD and 25 with MD) and 98 patients with dementia but without COPD (77.43±7.87 years old, 27 males and 71 females; 30 with AD, 31 with VD and 27 with MD) at two step model (interval of 2 years) with the following neuropsychological battery: Mini Mental State Examination (MMSE), Isaac's Set Test (IST), Literal fluency Test (LFT), Clock Drawing Test, 10 Words Test, Digit Symbol Substitution test (DSST), Digit Span Test (DST).

Results: Patients with COPD showed more pronounced decreases on global cognitive function (MMSE), LFT, IST, short-term memory and allocable attention vs those without. We failed to find any cognitive differences between patients with and without COPD at AD group. Patients with COPD and VD had low results on IST, LFT, working memory, delayed recall and working memory than those with VD but without COPD, they also showed significantly more prominent decline on LFT and Short-term memory. Patients with COPD and MD showed more prominent decline of global cognition (measured by MMSE) than those without COPD. They also had worse results DST forward.

Conclusions: COPD is associated with executive and memory changes and prominent deep white matter dysfunction. Patients with VD and MD and COPD are more vulnerable. It is unclear if COPD leads to COPD – associated cognitive changes or promotes other kinds of dementia.

**Keywords:** Chronic Obstructive Pulmonary Disease (COPD), Alzheimer's disease, vascular dementia, mixed dementia.

Introduction: The prevalence of Chronic Obstructive Pulmonary Disease (COPD) among elderly is 14-16% (Al Wachami, 2024). COPD is often associated with incident dementia and worsening of cognitive functions (Ranzini, 2020; Tao, 2020; Wang J, 2022; Rosso, 2023). The results of CAIDE study show association between COPD at middle ages and development of dementia 25 years after that, but not direct association between late onset COPD and degenerative dementia (Rusanen, 2013). According to Higbee et al. (2021) there is no causal relationship between Alzheimer's disease (AD) and COPD. Morris and al. (2019) obtained domain specific cognitive differences between patents with AD, with COPD and controls, suggesting that COPD leaded to different cognitive profile vs classical AD.

COPD is associated also with high risk for vascular dementia (VD) (Lahousse, 2015; Szylińska, 2022). Such patients have high stroke risk and low poststroke prognosis, because of low oxygen supply and high risk for pulmonary and systemic infections.

COPD may impact the brain function by several mechanisms: total and regional brain hypoxia and hypoxemia, particularly at night, associated with impaired night sleep, stimulation of oxidative stress and aseptic neuroinflammation, promotion of extra and intracerebral atherosclerosis, high level of pulmonary and systemic infections and worsening of heart and kidney functions because of whole body hypoxia and hypoxemia (Lahousse, 2015).

The aim of our study was to examine cognitive functions of patients with COPD in cases with AD, VD and mixed dementia (MD) and to compare them to those without COPD.

Material and methods: We examine 48 patients with mild COPD (on average 77.43±7.87 years old; 21 males, 27 females, 8 with AD, 15 with VD and 25 with MD) and 98 patients with dementia but without COPD (77.43±7.87 years old, 27 males and 71 females; 30 with AD, 31 with VD and 27 with MD). The inclusion criteria of the study were 1. Age ≥ 60 years; 2. Confirmed by neuropsychologist cognitive impairment at ≥2 cognitive domains; 3. Confirmed on the basis of history, neurological and somatic examination, laboratory data and imaging study diagnosis of AD or SVD or MD; 4. All patients are examined by pulmologist. Patients with COPD should have 0 to 1 stage of pulmonary failure. All patients with pulmonary failure above 1 stage are excluded; 5. All patients with obstructive sleep apnea are excluded; 6. Lack of other neurological diseases such as trauma, brain tumors, neuroinfections, demyelinating diseases or epilepsy; 7. Lack of decompensation of coexisted somatic diseases during the study; 8. Lack of psychiatric diseases, except of mild depression or anxiety; 9. Lack of treatment or usage of benzodiazepines, modafinile acetate, hallucinogens and other psychoactive drugs, except for low dosages of Quetiapine (≤50mg/d), Pregabaline (≤150mg/d), Gabaneural (≤600mg/d), Hydroxyzine (≤25mg/d) or antidepressants; 10. Lack of alcohol abuse or usage of forbidden substances; 11. Signed informed consent.

After clinical interview and confirmation of the diagnosis, the patients were examined via the following neuropsychological battery: Mini Mental State Examination (MMSE), Isaac's Set Test (IST for verbal fluency), Literal fluency Test (LFT; variant M-O-H-A in Bulgarian, 1 minute for every letter), Clock Drawing Test (CDT), 10 Words Test (for working memory, delayed recall and recognition (10/20words), Bulgarian

variant), Digit Symbol Substitution test (DSST 90sec), Digit Span Test (DST forward and backward) and 21 Hamilton Depression Scale (HDS). All patients with HDS above 12 points were excluded.

The same neuropsychological battery was used 2 years after the first examination.

The statistical analysis was done via parametric and non-parametric tests as ANOVA, MANOVA, Man-Whitney and Kruskal-Wallis test statistics via SPSS 20.0 and Statgraphics 20.0. All results were interpreted at 95% confidential level (p 0.05).

Results:

1. Demographic data.

Patients with COPD are 33% of all patients (see table 1). Our patients with and without COPD were at similar age. Male:female ratio was higher among COPD group (0.78 vs 0.38). Patients with COPD had slightly low formal education than those without.

2. The association between COPD and cognitive decline.

The differences between COPD and no COPD groups are given at table 2. Patients with COPD showed more pronounced decreases on global cognitive function (MMSE), literal and categorical fluency, short-term memory and allocable attention vs those without. We failed to find statistically significant intergroup differences on long-term memory, recognition, working memory, visual-spatial abilities and focused attention.

3. Cognitive differences between patients with and without COPD among patients with AD.

We failed to find any cognitive differences between patients with and without COPD at AD group. However, patients with AD and COPD were relatively few in number (N=8).

4. Cognitive differences between patients with and without COPD at VD group.

Patients with COPD and VD had low results on IST, LFT, working memory, delayed recall and working memory than those with VD but without COPD (see table 3). The group with COPD also showed significantly more prominent decline on LFT and Short-term memory during the period of 2 years. We failed to find intergroup differences on global cognition, recognition, attention and visual-spatial abilities (measured by CDT).

5. Associations between COPD and cognitive impairments among patients with MD.

Patients with COPD and MD showed more prominent decline of global cognition (measured by MMSE) than those without COPD (see table 4). They also had worse results on working memory test (DST forward). We failed to find intergroup differences on short and long term memory, information processing speed, visual spatial abilities and attention.

Discussion

COPD is frequent in elderly. About one third of our patients had mild COPD. The prevalence was highest at MD (51.29%), followed by VD (26.79%) and lowest at AD group (21.05%). COPD was 1.59 more frequent among male patients. Our patients with COPD were slightly low educated than those without. The higher male COPD prevalence is due to higher frequency of environmental and professional risk factors and Tabaco usage among men vs women (Al Wachami, 2024). Although our sample was relatively small and specific, we obtained significantly lower prevalence of COPD among patients with high vs basic formal education. Worldwide, low education level is associated with socio-economic and health problems and low quality of life (Lutter, 2020; Al Wachami, 2024). Moreover, patients with high education had better COPD outcome, lower complications and lower mortality rate than low educated (Lutter, 2020). So patients with basic education can be seen as a target group for the development of COPD associated complications. Among all our patients we found that those with COPD showed more prominent delay on global cognition, short-term memory and attention for a short time of 2 years than those without. Our results support the hypothesis of more prominent cognitive dysfunction and accelerated cognitive decline among patients with COPD vs those without (Wang Y, 2019; Ranzini, 2020; Tao, 2020; Wang J, 2022; Rosso, 2023). The previous studies associate COPD with global cognitive domain and domain specific cognitive impairments, although the more vulnerable cognitive domains differ from studies to studies. Tondo et al. (2018) suggest that the main cognitive impairments associated with COPD are frontal and executive dysfunctions. Morris et al. (2019) have found association between COPD and memory, attention and verbal fluency changes. Rosso et al. (2023) have found more prominent executive and episodic memory dysfunctions. Lahousse et al. (2015) obtained association between COPD and deep small vessel disease changes and development of dysexecutive syndrome firstly. Our data suggests also suggest more prominent changes at executive domain (information processing speed, short-term and working memory and partially attention). It remains unclear if COPD promotes the development and progression of dementia or it leads to different COPD associated dementia itself, which is superimposed over the coexisting other form of dementia (Tondo, 2018; Morris, 2019). Outside the decompensation of COPD, leading to infectious diseases, cor pulmonale or acute cerebral hypoxia, the most probable pathogenetic mechanisms for COPD associated cognitive dysfunctions are chronic hypoxia, hypoxemia, CO2 deposition, acidosis, changes at brain microcirculation leading to small vessels damage and promotion of neuro-inflammation and neurotransmitter dysbalance, activation of cortisol production and dysfunction of gliadin system (Tondo, 2018; Wang Y, 2019; Ranzini, 2020; Tao, 2020; Wang J, 2022; Rosso, 2023). COPD is a risk factor for worsening of other cognitive risk factors as cardiac dysfunction, atrial fibrillation, high risk for systemic infections and impaired night sleep (Lahousse, 2015; Szylińska, 2022). However, we failed to find association between COPD and worsening of AD, similar to other authors (Higbe, 2021). However, our sample was too little to draw conclusions. Morris et al. (2019) suggest different cognitive phenotype among patients with AD in relation with COPD although remains unclear if COPD really worsens AD associated cognitive decline. Tondo et al. (2018) obtained slightly worsening of executive functions in patients with COPD and AD vs those with "pure AD", but not worsening of global cognition or other additional domain-specific changes. We obtain statistically significant differences among patients with and without COPD among patients with VD. Patients with COPD show low categorical and literal fluency, low short-term memory, delayed recall and working memory, which might be associated with prominent

dysfunction of deep brain white matter and more prominent small vessels disease. It is found that COPD is associated with shrinkage of white matter, development of lacunar strokes, leucoareosis and microbleedings (Lahousse, 2015), leading to deficits of executive functioning and short-term memory (Tondo, 2018; Morris, 2019; Rosso, 2023). Concentrating on memory changes, we find short-term memory dysfunctions and changes at the level of information extraction from memory depo, but not in episodic memory itself, as stated Rosso et al. (2023). So the deficit is mostly because of disconnection but not at the level of hypocampal memory. However, the treatment of COPD might have some positive effect on cognition of patients with VD. And vice versa, the improvement of cognitive functioning might have positive effects on the COPD outcome (Siraj, 2023).

Our patients with MD and COPD showed the rapidest decline in global cognitive functioning and most prominent working memory deficits. It seems that global cognition is vulnerable to COPD in cases with MD, but not in with AD and VD. We fail to find any data for the impact of COPD among patients with MD at literature. We think that such patients should be target group for more wide studies on the question.

Cognitive dysfunction influences a number of important life aspects of patients with COPD. It can lead to functional dependence, unhealthy life, inappropriate respiration and rehabilitation. The major role for this plays executive dysfunctions and memory changes that lead to lack of self-control, lack of ability of independent taking care of yourself and low quality of life.

Conclusions

COPD is associated with executive and memory changes and prominent deep white matter dysfunction. Patients with VD and MD and COPD are more vulnerable. It is unclear if COPD leads to COPD – associated cognitive changes or promotes other kinds of dementia.

Table 1

Demographic data

| | AD | VD | MD | Total | Age (years) | M:F | B:M:H |
|---|---|---|---|---|---|---|---|
| Lack of COPD | 30 | 31 | 27 | 98 | 77.43±7.87 | 27:71 | 7:54:37 |
| COPD | 8 | 15 | 25 | 48 | 77.25±6.62 | 21:27 | 5:29:14 |
| | | | | p | >0.05 | 0.0001 | 0.0001 |
| Total | 38 | 56 | 52 | 146 | 76.71±7.47 | 48:98 | 12:83:51 |
| Legend: AD – Alzheimer's dementia, VD – vascular dementia, MD – mixed dementia; M:F – males:females; B:M:H – with basic, with middle. With high formal education. | | | | | | | |

Table 2

The difference between COPD and no COPD groups.

| Association between COPD and: | Averages or medianas of patients without COPD vs patients with COPD | p= |
|---|---|---|
| MMSE 1 (p.) | NA | p>0.05 |
| MMSE 2 (p.) | NA | p>0.05 |
| 2 year MMSE decline (p.) | -1.04±2.63 vs -2.02±2.79 | 0.0405 |
| IST1 (p.) | NA | p>0.05 |
| IST2 (p.) | 28.55±8.70 vs 25.42±8.11 | 0.0384 |
| 2 year IST decline (p.) | -1.5 vs -3.0 | 0.0117* |
| LFT 1 (p.) | NA | p>0.05 |
| LFT 2 (p.) | 20.94±11.40 vs 16.85±9.80 | 0.0432 |
| 2 year LFT decline (p.) | -2.0 vs -4.0 | 0.0263* |
| Short-term memory 10WT 1 (average words number from 5 trials) | NA | p>0.05 |
| Short-term memory 10WT 2 (average words number from 5 trials) | 4.68±1.62 vs 4.11±1.44 | 0.0132 |
| 2 year Short-term memory 10WT decline (average words number from 5 trials) | -0.2 vs 0.45 | 0.0434* |
| DSST 1 (p.) | NA | p>0.05 |
| DSST 2 (p.) | NA | p>0.05 |
| 2 year DSST decline (p.) | -2.0 vs -4.0 | 0.0405* |
| Legend: MMSE – Mini Mental State Examination, IST – Isaac's Set Test, Short term memory 10WT – Short – term memory 10 words test, DSST – Digit Symbol Substitution Test<br>*Kruskal-Wallis Test statistics | | |

Table 3

Association between COPD and cognitive impairment among patients with VD.

| Association between COPD and: | Medianas of patients without COPD vs patients with COPD | p= |
|---|---|---|
| IST1 (p.) | 36.0 vs 30.0 | 0.0178* |
| IST2 (p.) | 35.0 vs 29.0 | 0.0137* |
| 2 year IST decline (p.) | NA | p>0.05 |
| LFT 1 (p.) | NA | p>0.05 |
| LFT 2 (p.) | 28.5 vs 22.0 | 0.0331* |
| 2 year LFT decline (p.) | 0 vs -2 | 0.0326^ |
| Short-term memory 10WT 1 (average words number from 5 trials) | 6.0 vs 5.2 | 0.0386* |
| Short-term memory 10WT 2 (average words number from 5 trials) | 5.8 vs 5.0 | 0.0181* |
| 2 year Short-term memory 10WT decline (average words number from 5 trials) | 0.2 vs 0.4 | 0.0413* |
| 10WT DR 1 (number of words) | 5.0 vs 4.0 | 0.0294* |
| 10WT DR 2 (number of words) | 4.0 vs 3.0 | 0.0160* |
| 2 year delay on DR (number of words) | NA | p>0.05 |
| DST forward 1 (p.) | NA | p>0.05 |
| DST forward 2 (p.) | 7.0 vs 6.0 | 0.0099* |
| 2 year DST forward delay (p.) | NA | p>0.05 |
| Legend: IST – Isaac's Set Test, Short-term memory 10WT – Short-term memory from 10 words test, 10WT DR – delayed recall from 10 words test, DST – Digit Span Test<br>* Kruskal-Wallis Test Statistics. | | |

Table 4

The associations between COPD and cognitive impairments among patients with MD.

| The association between COPD and | Mediana without COPD vs with COPD | p= |
|---|---|---|
| MMSE 1 (p.) | NA | p>0.05 |
| MMSE 2 (p.) | NA | p>0.05 |
| 2 year MMSE decline (p.) | -1.0 vs -2.0 | 0.0460* |
| DST forward 1 (p.) | 3.0 vs 4.0 | 0.0484* |
| DST forward 2 (p.) | NA | p>0.05 |
| 2 year DST forward delay (p.) | NA | p>0.05 |
| Legend: MMSE – Mini Mental State Examination, DST – Digit Span Test; * Kruskal-Wallis. | | |

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# PEDAGOGY

## ЖАСАНДЫ ИНТЕЛЛЕКТІНІҢ ТҮРЛЕРІ МЕН ҚОЛДАНУ МҮМКІНДІКТЕРІ

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## TYPES AND APPLICATION POSSIBILITIES OF ARTIFICIAL INTELLIGENCE

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**Аңдатпа**

Мақалада жасанды интеллект өздігінен жұмыс істейтін бағдарлама емес, ол құрылғыларға қондырылған кезде ақпаратты анықтап, сараптап, біріктіру арқылы белгілі бір шешім шығаруға ұсыныс жасайды, ал кей жағдайларды сол шешімдерді өзі қабылдайды. Сонымен бірге жасанды интеллект жүйелері, жасанды интеллекттің негізгі түрлері, ЖИ-дің негізгі айырмашылықтары қарастырылған.

**Abstract**

The article considers that artificial intelligence is not an autonomous program that, when installed on devices, makes a suggestion about making a certain decision by identifying, analyzing and integrating information, and in some cases makes these decisions independently. At the same time, artificial intelligence systems, the main types of artificial intelligence, and the main differences between AI are considered.

**Кілт сөздер:** жасанды интеллект, бағдарлама, жасанды интеллект жүйелері, жасанды интеллекттің түрлері, ЖИ-дің негізгі айырмашылықтары.

**Keywords:** artificial intelligence, program, artificial intelligence systems, types of artificial intelligence, main differences of AI.

**Кіріспе.** Қарапайым тілмен айтқанда, ЖИ — адам миы сияқты ойлайтын, бірақ адам миы емес, математикалық алгоритмдер мен үлкен деректер негізінде жұмыс істейтін «жасанды ақыл».

«Жасанды интеллект» сөзін алғаш рет 1956 жылы Дартмут университетінде өткен конференциясының преамбуласында Джон Маккарти қолданған. Маккартиге сәйкес «жасанды интеллектті» зерттеушілер нақты проблеманы шешу үшін адамдарда байқалмайтын интеллектіні зерттеуіне болады [1].

Өзінің анықтамасын түсіндіру барысында: «Әзірше біз бүтіндей қандай есептеуіш процедураларды интеллектуалды деп айта алатынмызды білмейміз. Сол себепті интеллект сөзін әлемде мақсатқа жету үшін қолданылатын әдістердің есептеуіш бөлігін ғана түсініп жүрміз».[1]

Сонымен қатар, интеллект тек қана биологиялық феномен деген де көзқарастар бар.

Шындығында, жасанды интеллект Джон Маккартиге дейін де қолданылған. Тек оған дәл осы атау берілмеген болатын. Мысалы, екінші дүниежүзілік соғыс кезінде Алан Тюринг есімді ағылшын математигі немістің құпия ақпаратын бұзып, оны шифрдан шығаратын машина құрастырады.

Алан Тьюринг соғыс кезінде Германияның әскери-теңіз флотының хабарламаларына криптоанализ жасайтын ағылшын үкіметінің Hut 8 атауына ие тобына жетекшілік еткен. Ол немістердің Энигма аппаратының кодын бұзып, мыңдаған адамның өмірін сақтап қалады. Соғыстан кейін ағылшын ғалымы алгоритмдік анализ жасаумен айналысып, 1950 жылы компьютер интеллектінің деңгейін анықтайтын тест әдісін жасап шығарады. Тьюринг тесті бүгінгі күнге дейін қолданылады [2].

**Материалдар мен әдістер**. Жасанды интеллект жеке ғылыми бағыт ретінде XX ғасырдың екінші жартысында пайда болды (бұл көбінесе, кибернетиканың дамуына тәуелді болатын). Басқару талдау, салыстыру, ақпаратты өңдеу, болжамды жасау, жорамалдың дұрыстығын дәлелдеу (яғни интеллектуалды қызметіне жататын операциялар) негізінде шешімді қабылдаумен байланысты болады (оның негізгі мақсаты — есептеу жүйелері мен басқа да жасанды құрылғылардың көмегімен ақыл-ойға тән пайымдаулар мен әрекеттерді қайта жасау).

**Жасанды интеллекттің негізгі түрлері**

| Түрі | Атауы (ағылшынша) | Сипаттамасы | Қазіргі жағдайы (2026) | Мысалдар |
|---|---|---|---|---|
| Narrow AI → Тар ЖИ, Әлсіз ЖИ (Weak AI) | Artificial Narrow Intelligence (ANI) | Белгілі бір міндетті өте жақсы орындайды, бірақ басқа салада ештеңе істей алмайды | Барлығы қолданыста, күнделікті өмірде | ChatGPT, Midjourney, Tesla Autopilot, Google Translate, бет тану жүйелері |
| AGI → Жалпы ЖИ, Күшті ЖИ (Strong AI) | Artificial General Intelligence (AGI) | Адам сияқты кез келген интеллектуалдық міндетті орындай алады, жаңа салаға өз бетінше бейімделеді | Әлі жоқ, әзірлеу сатысында | — |
| ASI → Супер ЖИ, Асқан интеллект | Artificial Superintelligence (ASI) | Адам интеллектінен әлдеқайда жоғары, барлық салада және жылдамдықта адамнан мыңдаған есе артық | Толық гипотетикалық, AGI-дан кейін ғана мүмкін | — |

Қазіргі кезде (2026) біз тек тар ЖИ (ANI) деңгейінде тұрмыз**.** Барлық танымал модельдер (GPT-4o, Grok, Claude, Llama, Gemini т.б.) — тар мамандандырылған жүйелер.

*Адам интеллектісі мен ЖИ-дің негізгі айырмашылықтары:*

- **Сана мен түсінік** → Адамда бар, ЖИ-де жоқ (тек имитация)
- **Шығармашылық** → Адам жаңа салада интуициямен шешеді, ЖИ тек оқыған деректер шеңберінде «шығармашылық» жасайды
- **Эмоция, мораль, мотивация** → Адамда бар, ЖИ-де жоқ
- **Оқу тәсілі** → Адам аз мысалмен + рефлексия арқылы үйренеді, ЖИ миллиардтаған мысал қажет
- **Икемділік** → Адам білімді салалар арасында еркін қолданады, ЖИ әдетте бір тапсырмаға «байланады»

Қазіргі ЖИ не істей алады? (2026 мысалдар)

Тілдік модельдер — мәтін жазады, аударма жасайды, код жазады, сұраққа жауап береді

Сурет/видео генерация — Midjourney, Stable Diffusion, Runway, Sora

Дауыс синтезі — өте шынайы дауыс шығарады (Қазақша да дамып келеді)

Медицина — рентген, МРТ суреттерін талдап, ісікті ерте анықтайды

Автокөлік — Tesla FSD, Waymo жүргізушісіз көліктер

Бизнес — сұранысты болжайды, жарнама жекелендіреді, чат-боттар клиенттермен сөйлеседі

Білім — жекелендірілген тапсырмалар, тесттерді тексеру, түсіндіру

*Жасанды интеллект жүйелері* — арнайы логикалық жүйелер арқылы компьютерлік бағдарламада жүзеге асырылған адам интеллектің жеке аспектісін ұдайы өндіретін техникалық жүйелер. Жасанды интеллект жүйелерінің қолдану салалары:

- роботтехника
- сараптамалық жүйелер;
- есептерді әмбебап шешушіні жасау;
- бір тілден екінші тілге аудару, мәтінді рефераттау;
- пайдаланушыны компьютермен ыңғайлы диалогын қамтамасыз ететін интеллектуалды интерфейсты жасау.

Өткен ғасырдың соңғы он жылдығында интеллектуалды жүйелер дамуының келесі маңызды бағдарлары анық көрінді:

1. Шығармашылық үдерістерді еліктейтін жүйелер. Музыкалық шығармаларды жасау, ойын есептерді (шахмат, дойбы, домино) шешу, автоматтандырылған аударма, теоремаларды дәлелдеу, бейнелерді айырып тану, ойлауды еліктеу және т.с.с.

2. Білімдерге негізделген (сараптау жүйесі) ақпараттық жүйелер, яғни жабдықтарды күйге келтіру, тәжірибелі емес пайдаланушыларға кеңес беру, оқыту және т.б.

3. Интеллектуалды ақпараттық жүйелер – заттық салада есептерді шешуге арналған математикалық және алгоритмдық модельдерге негізделген үлкен және өте үлкен бағдарламалар. Олардың мүмкіндігі: басқаруды оңайлату және адамның жұмыс көлемін азайту үшін пайдаланушымен мағыналы сұхбат жүргізу.

4. Роботтық техника. «Интеллектуалдығы» жағынан бірнеше робот буындарын ажыратады. *Бірінші буын* — алдын ала бекітілген және өзгермейтін бағдарлама бойынша істейтін робот-манипуляторлар (мысалы, станокқа дайындамаларды әперетін). *Екінші буын* – бейімделген роботтар. Ондай роботтар әртүрлі датчиктермен (бұрыш өлшеуіштері, тензометрлер, газ талдаушылар және т.б.) жабдықталған. Роботтардың алғашқы екі түрі — өнеркәсіптік роботтар, олар арнайы ортада (зауыт цехында) жұмыс істеуге арналған.

Жасанды интеллект дамуының екі бағыты бар:

- мамандандырылған жасанды интеллект жүйелерін адам мүмкіндіктеріне жақындатумен және олардың адам табиғатымен жүзеге асырылатын интеграциясымен байланысты мәселелерді шешу;
- бұрыннан жасалған жасанды интеллект жүйелерін адамзаттың мәселелерін шешуге қабілетті бір жүйеге біріктіруді білдіретін жасанды интеллект құру.

ЖИ — машинаға негізделген жүйе, ол белгілі бір мақсаттарға жету үшін болжам жасай алады, ұсыныс береді немесе шешім қабылдай алады. АҚШ Мемлекеттік департаментінің және IBM-дің соңғы анықтамаларына сәйкес, ЖИ адам сияқты шынымен түсінбейді, эмоция сезбейді және санаға

ие емес — тек күрделі статистикалық үлгілер мен есептеулер арқылы жұмыс істейді [3].

**Нәтижелер. Егер соңғы тенденцияларға қарайтын болсақ, жасанды интеллект деген тіркесті жиі естиміз. Үйіміз, көлігіміз, тіпті тостерімізге дейін өзі ойланып, өзі жұмыс істейтін деңгейге жеткен.**

Ендігі кезекте жасанды интеллектінің қолданыс тапқан салалары мен түрлеріне назар аударсақ:

**Автоматты үйрену.** Енгізілген мәліметті анықтап, классификациялау үшін моделдерді құрастырып, сынақтан өткізіп, кері бағытта қайтару принципімен жұмыс істейтін мәліметтер базасындағы жүйе.

**Мақсатты үйрену.** Белгілі бір мақсатқа жеткен кезде оны қуаттандыратын жүйе. Ол көбінде агенттік жүйелерде қолданылады.

**Терең үйрену.** Бұл жүйелер автоматты үйрену жүйесін құру үшін сызықтық емес нейрондық тармақтармен жұмыс істейді. Жоғарыда айтып кеткен автоматты үйренудің өзгеше нейрондармен жұмыс істейтін түрі.

**Агенттік жүйелер.** Тәуелсіз агенттер белгілі бір ортада қарым-қатынасқа түсіп, массалық әрекеттердің (араның топтасып ұшқаны сияқты) симуляциясын жасайды. Бұл әдіс көбінде ойындарда және басқа да симуляцияларда қолданады.

**Сызықтық емес тораптар жүйесі.** Агенттік жүйенің түрөзгерісі. Белгілі өлшемдегі тораптар ішкі жағдайды сақтайды, онымен қоса жанындағы ұяшықтардың әсерінен, мәліметті сыртқа шығарады. Конуейдің Game of Life бағдарламасы осы жүйенің бастапқы нұсқасы болатын, кейіннен оның күрделі әрі кері бағытта жұмыс істейтін үлгісі биржадағы акцияларды моделдеу мен болжам жасауға қолданатын болды.

**Өздігінен өзгеретін графикалық жүйелер.** Ақпараттар базасындағы жағдай ондағы түйіндерді шешудің жаңа әдістерін тапқанда (эвристикалық әдіс) өзгеріп тұрады.

**Білім базалары, бизнес интеллект және эксперттік жүйелер.** Қалыпты мәліметтер базасындағы кестелерден семантикалық білім спектрумын құрастырады. Кей жағдайларда бұл процесс адамның бақылауымен болса, кейбір бағдарламалар автоматты үйренуге ауысып, мәліметтер өздігінен іріктеліп, топтасып және бір-бірінен бөлінеді.

**Виртуалды кеңесші мен ақылды агенттер.** Бұл агенттік жүйеден аздап өзгешелеу. Агенттер ақпараттық жүйедегі жазбаша немесе ауызша мәтінді өңдеп, одан белгілі мәліметті іріктеп, керектісін шығарып береді және басқа да операциялар жасайды. 1960 жылдардағы Элиза жүйесі алғашқы қарапайым агент еді. Қазіргі агенттер мен виртуалды кеңесші семантикалық комбинация, Байес анализін, автоматты үйренуді қолданып, қажетті мәлімет беріп, қолданушы жайлы ақпарат жинайды [4].

**Визуалды суреттер мен аудио дыбыстарды оқитын жүйелер**. Көп жағдайларда визуалды және аудио жүйелер медиа материалды кішірейтілген кодталған сұраққа айналдырып, содан кейін алгоритмдегі индекстер арқылы немесе автоматты жүйедегі ең сәйкес нұсқамен салыстырады. Ол көбінде арнайы бөлшектердің кездесу жиілігіне байланысты сарапталатын және бір-бірімен байланысатын семантикалық жүйелерден тұратын Байес анализімен жұмыс істейді.

**Бөлшектік визуализация.** Фрактал бөлшектер мен жасанды интеллектің байланысы өте терең болуымен қатар, параметрленген табиғи көріністер: судың ағуы, оттың ұшқыны, тастардың бедері, ауадағы түтін сияқты Голливуд фильмдеріндегі арнайы эффектілерді жасау жасанды интеллектің ең кең дамыған саласы саналады.

Сонымен қатар ЖИ «кеңістікте» де өз қолданысын тапқан:

**Өздігінен басқарылатын көліктер.** Бұл визуалды тану жүйесі мен шынайы уақыт моделінде жұмыс істеу арқылы көлік «көз» алдындағы кедергілерді (статикалық және қозғалмалы) көріп, алған бағытына байланысты әрекет етеді.

**Дрондар.** Дрон жолаушысы жоқ өздігінен басқарылатын көлік, ол жарқанат сияқты кішкентай өлшемнен басталып, реактивті ұшақтың көлеміндей үлкен болады. Олар алыстан да басқарылады, ара сияқты топтасып ұшып немесе алдын ала қойылған программамен де ұшады.

**Мәліметтерді сараптау.** Қолдағы бар мәліметтерді сараптау арқылы үлгілерді анықтап, алда болатын оқиғаларға болжам жасау. Бұл автоматты үйрену техникасы мен сандық статистикалық анализ, сызықтық емес дифференциялық теңдеулерді қолданады. Мәлімет сараптауда ғалымдар жоғары деңгейдегі функциялар мен қайталау әдісін қолданбайды, сәйкесінше бұл сала әлі де даму үстінде.

Сонымен қатар, жасанды интеллект блокчейндер, қаражат аудару мен оны бақылау саласында, интернет құрылғыларын байланыстыру мен интеллектуалды камераларда қолданылады.

Бір сөзбен айтқанда, жасанды интеллект өздігінен жұмыс істейтін бағдарлама емес, ол құрылғыларға қондырылған кезде ақпаратты анықтап, сараптап, біріктіру арқылы белгілі бір шешім шығаруға ұсыныс жасайды, ал кей жағдайларды сол шешімдерді өзі қабылдайды. Ең бастысы бұл тренд әлі де дамып, жалғасын табады.

**Жасанды интеллект** — бұл қазірдің өзінде өміріміздің барлық саласына енген қуатты құрал. Ол адамның орнына толық келе алмайды, бірақ адамның қабілетін күшейтеді, рутиналық жұмыстарды жеделдетеді және бұрын мүмкін емес нәрселерді жасайды.

**Ең маңыздысы:** ЖИ — құрал. Оны қалай және қайда қолданатынымыз адамның қолында. Сондықтан **этика, қауіпсіздік және адам бақылауы** әрқашан бірінші орында болуы керек

Қазақстан ЖИ-ді дамыту үшін интернет инфрақұрылымын күшейтіп жатыр. 2025 жылғы шілдеде өткен цифрландыру жөніндегі комиссия отырысында премьер-министр Олжас Бектенов ұлттық AI инфрақұрылымын дамыту және жаңа Суперкомпьютер құру туралы бастама көтерді. Қазіргі уақытта үкімет деректер орталықтарын жаңғырту арқылы ЖИ жүйелері үшін жоғары есептік қуат қамтамасыз етуде. Министр Зhaслан Мадиев 2024–

2029 жылдарға арналған AI Development Concept және заң жобаларының іске асырылу барысы туралы баяндап, e-agent, egov AI, AI-therapist, tax helper, SDU және E-translator сияқты цифрлық шешімдердің таныстырылғанын айтты. Бұл құралдар мемлекеттік қызметтерді жылдам әрі тиімді етуге бағытталған.

ЖИ технологияларын тиімді енгізу үшін мамандар даярлау шешуші факторға айналды. Қазақстандық билік бұл бағытта ауқымды жоспар жасауда: цифрлық даму министрі Жаслан Мадиев алдағы бес жылда 1 миллион адамды жасанды интеллект бойынша оқыту мақсат екенін мәлімдеді. Бұл бастама мектеп оқушылары, студенттер, мемлекеттік қызметкерлер және бизнес өкілдерін қамтиды. Ғылым және жоғары білім министрі Саясат Нұрбек 27 университет пен 6 зерттеу институтында 479 ғалым ЖИ бойынша зерттеу жүргізіп жатқанын, 2025 жылдан бастап ЖИ дағдылары барлық оқу бағдарламаларына енгізілетінін айтты.

Парламенттік тыңдауларда ЖИ-ді табиғи ресурстарды басқаруда қолдану мәселесі қозғалды: су ресурстарының деңгейін, сапасын және ластануын талдау, су тасқыны мен құрғақшылықты болжау, техногендік апаттардың алдын алу бойынша ұсыныстар айтылды.

Қоғамдық сауалнамалар Қазақстан азаматтарының ЖИ-ге қатысты көзқарасының екіге бөлінгенін көрсетеді: 40,5% азамат технологияны жағымды бағаласа, 37% білім сапасы төмендейді деп алаңдайды. Бұл пікірлер мемлекет үшін ақпараттық түсіндіру жұмыстарын күшейту қажет екенін білдіреді [5].

**Қорытынды**. Жасанды интеллект – адамзат дамуының жаңа кезеңін білдіретін ғаламдық құбылыс. Оның мүмкіндіктері экономиканы, мәдениетті, ғылымды, қоғамды өзгертіп қана қоймай, жаңа тәуекелдер мен моральдық сұрақтарды да туындатты. Бұл мақалада біз ЖИ-дің ғылыми анықтамасын ашып, әлемдегі қолдану статистикасын, пайдасы мен қауіп-қатерін, халықаралық реттеудің трендтерін және Қазақстандағы ахуалды жан-жақты талдадық.

Алдағы жылдары Қазақстан ЖИ-ді мемлекеттік басқаруда, ауыл шаруашылығында, денсаулық сақтауда, білім беруде және табиғи ресурстарды басқаруда кеңінен пайдалана алады. Бұл үшін халықаралық тәжірибені зерделеп, этикалық нормаларды сақтап, қоғаммен тұрақты диалог жүргізу маңызды. ЖИ-дің толық әлеуетін іске асыру үшін тілдік және технологиялық теңсіздікті жою, кадрларды даярлау және зерттеу экожүйесін дамыту қажет.

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# SƏRİŞTƏYƏ ƏSASLANAN TƏHSİLİN NƏZƏRİ ƏSASLARI VƏ MÜASİR TƏTBİQ TƏCRÜBƏLƏRİ

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# THE THEORETICAL FOUNDATIONS OF COMPETENCY-BASED EDUCATION AND MODERN APPLICATION PRACTICES

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**Xülasə**

Müasir dövrdə təhsil sistemlərinin əsas məqsədlərindən biri şagirdlərin yalnız bilik əldə etməsini deyil, həmin bilikləri real həyatda tətbiq edə bilən səriştələrə yiyələnməsini təmin etməkdir. Bu baxımdan səriştəyə əsaslanan təhsil (Competency-Based Education – CBE) ənənəvi vaxt əsaslı təlim modelinə alternativ olaraq xüsusi aktuallıq qazanmışdır. Məqalədə səriştəyə əsaslanan təhsilin nəzəri əsasları, formalaşma xüsusiyyətləri və müasir tətbiq təcrübələri təhlil edilmişdir. CBE-nin əsas prinsipləri, struktur elementləri və ABŞ təhsil sistemində tətbiqinə dair nümunələr təqdim olunmuşdur. Eyni zamanda, bu yanaşmanın tətbiqi zamanı yaranan çətinliklər və perspektiv imkanlar araşdırılmışdır. Aparılan təhlil göstərir ki, səriştəyə əsaslanan təhsil şagirdyönümlü, fərdiləşdirilmiş və ədalətli təhsil mühitinin formalaşdırılmasına mühüm töhfə verir. [10]

**Abstract**

In the contemporary era, one of the primary objectives of education systems is not only to ensure that learners acquire knowledge, but also to enable them to develop competencies that allow for the effective application of this knowledge in real-life contexts. From this perspective, competency-based education (CBE) has gained particular relevance as an alternative to the traditional time-based instructional model. This article examines the theoretical foundations of competency-based education, its developmental characteristics, and modern implementation practices. The core principles and structural components of CBE are analyzed, and examples of its application within the United States education system are presented. In addition, the challenges encountered in the implementation of this approach, as well as its prospective opportunities, are explored. The analysis indicates that competency-based education makes a significant contribution to the establishment of a learner-centered, personalized, and equitable educational environment.

**Açar sözlər:** Səriştəyə əsaslanan təhsil, şagirdyönümlü təlim, fərdiləşdirilmiş öyrənmə, qiymətləndirmə, təhsil islahatları.

**Keywords:** Competency-based education, learner-centered instruction, personalized learning, assessment, educational reforms.

**Mövzunun aktuallığı:** Qloballaşma, əmək bazarının tələblərinin dəyişməsi və bilik cəmiyyətinə keçid müasir təhsil sistemləri qarşısında yeni vəzifələr qoyur. Ənənəvi təlim modelləri şagirdlərin real bacarıq və səriştələrinin inkişafını hər zaman təmin edə bilmir. Bu baxımdan səriştəyə əsaslanan təhsil yanaşması təhsildə keyfiyyətin yüksəldilməsi, fərdiləşdirilmiş öyrənmənin təşviqi və bərabər təhsil imkanlarının yaradılması baxımından xüsusi aktuallıq kəsb edir. Müasir təhsil islahatları kontekstində CBE-nin nəzəri və praktik aspektlərinin öyrənilməsi aktual elmi-pedaqoji problem kimi çıxış edir.

**Materialı və metodika**: Tədqiqatın əsas məqsədi səriştəyə əsaslanan təhsilin nəzəri əsaslarını və müasir tətbiq təcrübələrini araşdırmaq, bu yanaşmanın təhsil sistemində rolunu və əhəmiyyətini müəyyənləşdirməkdir.

Bu məqsədə nail olmaq üçün səriştəyə əsaslanan təhsilin mahiyyətinin və əsas prinsipləri təhlil edilmiş, struktur elementləri müəyyənləşdirilmiş, müasir beynəlxalq, xüsusilə ABŞ təcrübəsində səriştəyə əsaslanan təhsilin tətbiqinin araşdırılmışdır. Bunlarla yanaşı bu yanaşmanın tətbiqi zamanı yaranan çətinliklərin və perspektiv imkanların dəyərləndirilməsi həyata keçirilmişdir.

**Tədqiqatın obyekti** müasir təhsil sistemində tətbiq olunan alternativ təlim yanaşmalarıdır. **Tədqiqatın predmeti** səriştəyə əsaslanan təhsilin nəzəri əsasları, struktur elementləri və müasir tətbiq təcrübələridir. **Tədqiqatın metodları** kimi elmi ədəbiyyatın təhlili, müqayisəli analiz, normativ sənədlərin öyrənilməsi və mövcud təhsil təcrübələrinin ümumiləşdirilməsi metodlarından istifadə olunmuşdur.

**Təhlil və müzakirə:** Səriştəyə əsaslanan təhsil şagirdlərin təlim prosesində fəal iştirakını, biliklərin tətbiqini və mənimsəmənin nümayiş etdirilməsini əsas götürən bir yanaşmadır. Bu model aktiv bilik quruculuğu, fərdiləşdirilmiş öyrənmə və ustalığa əsaslanan irəliləyiş prinsiplərinə söykənir. CBE yanaşmasının formalaşması nəticəyə əsaslanan təhsil ideyaları ilə sıx bağlıdır və XX əsrin ikinci yarısından etibarən inkişaf edərək müasir qiymətləndirmə mexanizmləri və təhsil texnologiyaları ilə zənginləşmişdir. [9]

Sərişləyə əsaslanan təhsilin əsas elementləri 2019-cu ildə Aurora İnstitutu tərəfindən yenidən işlənmiş tərifə əsasən, sərişləyə əsaslanan təhsil yeddi əsas elementi əhatə edir. Bu elementlər şagirdlərin öyrənmə prosesində qərarvermə səlahiyyətinə malik olmasını, qiymətləndirmənin öyrənməni dəstəkləyən müsbət təcrübə kimi qurulmasını, fərdi ehtiyaclara uyğun vaxtında dəstəyin göstərilməsini və irəliləyişin mənimsəmə dəlillərinə əsaslanmasını nəzərdə tutur. Eyni zamanda, öyrənmədə çevik temp, müxtəlif yanaşmaların tətbiqi, bərabərliyi təmin edən strategiyaların sistemə inteqrasiyası və aydın, ölçülə bilən təlim gözləntiləri CBE-nin əsas xüsusiyyətləri kimi çıxış edir.[1]

Güclü tətbiq yalnız bu elementlərin mövcudluğu ilə məhdudlaşmır, həm də siyasət, pedaqogika, struktur və məktəb mədəniyyətinin hər bir şagirdin əsas sərişlələrinin inkişafını dəstəkləyəcək şəkildə qurulmasını tələb edir. [6]

Orta Qərb Regional Təhsil Laboratoriyası (REL Midwest) sərişləyə əsaslanan təhsilin əsas xüsusiyyətlərini dörd əsas təhsil təcrübəsində ümumiləşdirmişdir. Bu təcrübələrə konkret və ölçülə bilən təlim məqsədlərinin müəyyən edilməsi, şagirdlərin bu məqsədlərə nail olduqlarını nümayiş etdirmələri üçün imkanların yaradılması, çevik temp və fərdiləşdirilmiş təlim şəraiti, eləcə də hər bir şagirdin ehtiyaclarına uyğun dəstəyin göstərilməsi daxildir. [5] [8]

Bu yanaşma məktəblərə təlim prosesini fərdiləşdirməyə, şagirdlərin mövzunu daha dərindən mənimsəməsinə və öz sürətləri ilə irəliləməsinə imkan verir. Zamana əsaslanan sistemdən ustalığa yönəlmiş sistemə keçid təhsildə bərabərliyin və iştirakın artırılmasına xidmət edir.

ABŞ-da artıq bütün ştatlar məktəblərə şagirdlərin irəliləyişini dərsdə keçirdikləri vaxta deyil, mənimsəmə səviyyəsinə əsasən müəyyən etməyə icazə verir. Milli səviyyədə bir sıra ştatlar CBE-ni dəstəkləyən siyasətləri tətbiq etmiş, bəziləri isə bu yanaşmanı pilot layihələr vasitəsilə sınaqdan keçirmişdir. Nyu-Hempşir və Men ştatları erkən dövrlərdə qanunvericilik dəyişiklikləri edərək qiymətləndirmə və kredit sistemində çevikliyi artırmışdır. Digər ştatlar isə innovativ proqramlar vasitəsilə sərişləyə əsaslanan təhsilin inkişafını təşviq etmişdir. [7]

Bu təşəbbüslərin əsas məqsədləri şagird iştirakını artırmaq, təlimi fərdiləşdirmək, əmək bazarına hazırlığı gücləndirmək və nailiyyət fərqlərini azaltmaqdan ibarət olmuşdur.

Sərişləyə əsaslanan təhsilin tətbiqi bir sıra çətinliklərlə müşayiət olunur. Əsas problemlərdən biri maraqlı tərəflər arasında kifayət qədər anlayış və dəstəyin olmaması, resurs çatışmazlığı və ənənəvi təlim modelindən imtina ilə bağlı psixoloji müqavimətdir. Tədris metodlarının, tədris dizaynının və qiymətləndirmə yanaşmalarının dəyişdirilməsi müəllim və idarəçilər üçün ciddi adaptasiya tələb edir. Bəzi tənqidçilər CBE-nin müəyyən fənlər üçün uyğun olmaya biləcəyini və yüksək riskli qiymətləndirmələrə həddindən artıq bağlılıq yarada biləcəyini qeyd edirlər. [2] [3]

Bununla belə, aparılmış tədqiqatlar, xüsusilə akademik cəhətdən geridə qalan şagirdlər üçün riyaziyyat və dil fənlərində müsbət nəticələrin müşahidə olunduğunu göstərir. [4]

**Nəticə**: Aparılan təhlil göstərir ki, sərişləyə əsaslanan təhsil şagirdyönümlü yanaşmaların gücləndirilməsi baxımından mühüm potensiala malikdir. Bu model təhsildə çeviklik, fərdiləşmə və ədalətli imkanların yaradılmasına xidmət edir. Lakin CBE-nin uğurlu tətbiqi üçün sistemli yanaşma, institusional dəstək və pedaqoji mədəniyyətin transformasiyası zəruridir. Bu baxımdan sərişləyə əsaslanan təhsil müasir təhsil islahatlarının perspektivli istiqamətlərindən biri kimi qiymətləndirilə bilər.

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# ONCE AGAIN ABOUT THE VARIATIVE APPROACH TO PROBLEM SOLVING IN THE PROCESS OF TEACHING MATHEMATICS

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**Abstract**
Many mathematical problems admit interesting and effective solution methods. Quite often these methods differ significantly from one another both in idea and in external form. Becoming familiar with such methods gives students the opportunity to consider the essence of a problem from different perspectives. As a result, creative thinking, breadth of approach, and a non-formal, deeper understanding of the learning material are formed.

The article examines various aspects of this approach and presents corresponding problems from the school mathematics course [1].

**Keywords.** variative approach, method, creative thinking, deep understanding, number line, proof, triangle, circle, area, volume.

Introduction

Solving problems in different ways has important methodological significance and provides great opportunities for improving the process of teaching mathematics [2].

First, searching for different solution methods is one of the effective ways of implementing the didactic principles of conscious and active assimilation of educational material [4]. When solving the same problem by different methods, a known exercise is often transferred to qualitatively new conditions and repeated in new connections and combinations [3].

Second, in order to solve problems in different ways, students have to analyze many theoretical facts, methods, and techniques from the point of view of their applicability to a given situation, which contributes to the formation and development of flexibility of thinking.

Third, in the process of searching for various solution methods for one problem, creative thinking predominates. This contributes to the development not only of intellect but also of a number of moral qualities and largely determines a student's worldview. In addition, solving problems in different ways also serves aesthetic education [4]. It is here that students learn to independently find simpler and more elegant solutions, begin to see the interrelation of all parts of mathematics, and thus appreciate the beauty of this science.

Below are examples of solving problems in different ways.

Examples of Variative Solutions

***Example 1: Inequality***

Prove that for $x \geq 0$ the inequality

$$x + 3 \geq 4\sqrt[4]{x}$$

holds.

Method I.

Let $t = \sqrt[4]{x}$. Then the inequality becomes

$$t^4 - 4t + 3 \geq 0.$$

Factor the left-hand side. Since the polynomial $t^4 - 4t + 3$ is divisible by (t-1), we obtain

$$t^4 - 4t + 3 = (t-1)(t^3 + t^2 + t - 3).$$

The cubic factor is also divisible by $(t-1)$:

$$t^3 + t^2 + t - 3 = (t-1)(t^2 + 2t + 3).$$

Hence

$$t^4 - 4t + 3 = (t-1)^2(t^2 + 2t + 3).$$

Since $t^2 + 2t + 3 > 0$ for all real $t$, the inequality reduces to $(t-1)^2 \geq 0$, which is always true. Equality occurs when $t = 1$, i.e. $x = 1$. Thus the original inequality holds for all $x \geq 0$, with equality only at $x = 1$.

Method II.

Write $x + 3 = (x + 1) + 2$. By the Cauchy inequality (AM–GM),

$$\frac{x+1}{2} \geq \sqrt{x} \quad \Rightarrow \quad x + 1 \geq 2\sqrt{x}.$$

Therefore,

$$x + 3 \geq 2\sqrt{x} + 2.$$

Now apply Cauchy again to the numbers $2\sqrt{x}$ and 2:

$$\frac{2\sqrt{x} + 2}{2} \geq \sqrt{(2\sqrt{x}) \cdot 2},$$

which simplifies to

$$2\sqrt{x} + 2 \geq 2\sqrt{4\sqrt{x}} = 4\sqrt[4]{x}.$$

Combining, we obtain $x + 3 \geq 4\sqrt[4]{x}$. Equality occurs when $x + 1 = 2\sqrt{x}$ and $2\sqrt{x} = 2$, i.e. $x = 1$.

***Example 2: Absolute Value Equation***

Solve the equation

$$|x + 1| + |x - 3| = 4.$$

Method I (Case analysis).

We consider the sign of each absolute value.

- **Case a:** $x + 1 \geq 0,\ x - 3 \geq 0$ i.e. $x \geq 3$. Then equation becomes $(x + 1) + (x - 3) = 4 \Rightarrow 2x - 2 = 4 \Rightarrow x = 3$. This satisfies the condition, so $x = 3$ is a solution.
- **Case b:** $x + 1 \geq 0,\ x - 3 < 0$ i.e. $-1 \leq x < 3$. Then $(x + 1) - (x - 3) = 4 \Rightarrow 4 = 4$, which holds for every $x$ in this interval. So all $x \in [-1,3)$ are solutions.
- **Case c:** $x + 1 < 0,\ x - 3 \geq 0$ i.e. $x < -1$ and $x \geq 3$ — impossible.
- **Case d:** $x + 1 < 0,\ x - 3 < 0$ i.e. $x < -1$. Then $-(x + 1) - (x - 3) = 4 \Rightarrow -x - 1 - x + 3 = 4 \Rightarrow -2x + 2 = 4 \Rightarrow x = -1$. But $x = -1$ does not satisfy $x < -1$, so no solution.

Thus the solution set is $[-1,3]$.

Method II (Geometric interpretation on the number line).

The numbers $-1$ and 3 divide the real line into three intervals (see Fig. 1), on each of which the expressions inside absolute values have constant sign.

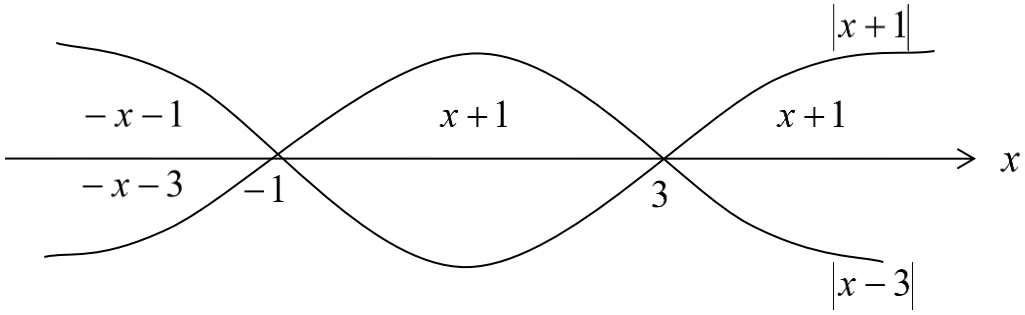


*Figure 1: Number line divided at −1 and 3.*

- Interval $(-\infty, -1)$: both expressions negative, equation $-(x + 1) - (x - 3) = 4$ gives $x = -1$ (not in interval) → no solution.
- Interval $[-1,3]$: $x + 1 \geq 0,\ x - 3 \leq 0$ → equation $(x + 1) - (x - 3) = 4$ gives identity → all $x$ in this interval satisfy.
- Interval $(3, \infty)$: both positive → $(x + 1) + (x - 3) = 4$ gives $x = 3$ (boundary included).

***Example 3: Geometry (Triangle and Inscribed Circle)***

A circle with its centre on side $AC$ of an isosceles triangle $ABC$ $(AB = BC)$ is tangent to sides $AB$ and $BC$. Find the radius of the circle if the area of triangle $ABC$ is 25 and the ratio of the height $BO$ to side $AC$ is $\frac{3}{8}$ [5].

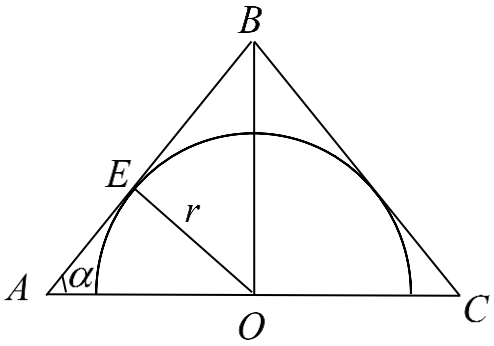


*Figure 2: Isosceles triangle with inscribed circle.*

Solution.

Let $O$ be the midpoint of side $AC$ (the centre of the circle lies on $AC$; by symmetry it is the midpoint). Let $E$ be the tangency point on $AB$; then $OE \perp AB$ and $OE = r$. Set $BO = 3x$; from the given ratio $BO: AC = 3: 8$ and

$AO = \frac{1}{2}AC$ we obtain $AO = 4x$. In right triangle $AOB$ (since $BO$ is the altitude to the base in an isosceles triangle) we find $AB = \sqrt{(3x)^2 + (4x)^2} = 5x$.

The area of triangle $ABC$ is $S = \frac{1}{2} \cdot AC \cdot BO = \frac{1}{2} \cdot (8x) \cdot (3x) = 12x^2$. Given $S = 25$, we get $12x^2 = 25 \Rightarrow x = \frac{5}{2\sqrt{3}}$.

In right triangle $AOB$, the altitude from the right angle $O$ to the hypotenuse $AB$ is exactly $r$ because $OE \perp AB$. From similarity of triangles, $\frac{OE}{AO} = \frac{BO}{AB}$, i.e. $r = \frac{3x \cdot 4x}{5x} = \frac{12x}{5}$. Substituting $x$ gives $r = \frac{12}{5} \cdot \frac{5}{2\sqrt{3}} = \frac{6}{\sqrt{3}} = 2\sqrt{3}$.

Alternative method (trigonometry).

Let $\angle BAO = \alpha$. Then $\tan\alpha = \frac{BO}{AO} = \frac{3x}{4x} = \frac{3}{4}$, so $\sin\alpha = \frac{3}{5}$. The area can also be written as $S = BO \cdot AO = 12x^2 = 25$, hence $x = \frac{5}{2\sqrt{3}}$. In right triangle $AOB$, the altitude $r = AO\sin\alpha = 4x \cdot \frac{3}{5} = \frac{12x}{5} = 2\sqrt{3}$.

***Example 4: Right Triangle with a Perpendicular***

In an isosceles right triangle $ABC$ ($\angle C = 90°$, $AC = BC$), let $D$ be a point on side $AC$. Draw line $BD$, and from $C$ drop a perpendicular to $BD$ meeting side $AB$ at $M$. Prove that

$$\frac{AM}{BM} = \frac{DC}{AC}.$$

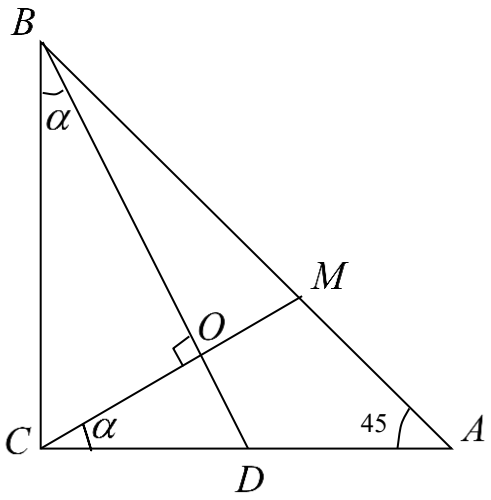


*Figure 3: Right triangle with perpendicular CM.*

*Method I (Law of sines).*

Set $\angle ACM = \alpha$. In $\triangle ACM$ and $\triangle BCM$ we apply the law of sines:

$$\frac{AM}{\sin\alpha} = \frac{CM}{\sin 45°}, \qquad \frac{BM}{\sin(90° - \alpha)} = \frac{CM}{\sin 45°}.$$

Thus

$$\frac{AM}{CM} = \frac{\sin\alpha}{\sin 45°}, \qquad \frac{BM}{CM} = \frac{\cos\alpha}{\sin 45°},$$

and consequently

$$\frac{AM}{BM} = \tan\alpha.$$

Now we relate $\alpha$ to the position of $D$. Because $CM \perp BD$, the angles $\alpha$ and $\angle BDC$ are complementary (or use coordinate geometry). Place the triangle in a coordinate system: let $C = (0,0)$, $A = (1,0)$, $B = (0,1)$ (since $AC = BC = 1$; the ratio is scale-invariant). Then $D = (d, 0)$ with $0 < d < 1$ (so $DC = d$, $AC = 1$). The line $BD$ goes through $B(0,1)$ and $D(d, 0)$; its slope is $-\frac{1}{d}$. The perpendicular $CM$ therefore has slope $d$ and equation $y = dx$. Side $AB$ has equation $x + y = 1$. Intersection $M$ is obtained from $x + dx = 1 \Rightarrow x = \frac{1}{1+d}$, $y = \frac{d}{1+d}$. Then

$$AM = \sqrt{\left(1 - \frac{1}{1+d}\right)^2 + \left(0 - \frac{d}{1+d}\right)^2} = \frac{\sqrt{2}\,d}{1+d},$$

$$BM = \sqrt{\left(0 - \frac{1}{1+d}\right)^2 + \left(1 - \frac{d}{1+d}\right)^2} = \frac{\sqrt{2}}{1+d}.$$

Hence $\frac{AM}{BM} = d = DC$. Since $AC = 1$, we have $\frac{AM}{BM} = \frac{DC}{AC}$. Combining with the previous result $\tan\alpha = \frac{DC}{AC}$.

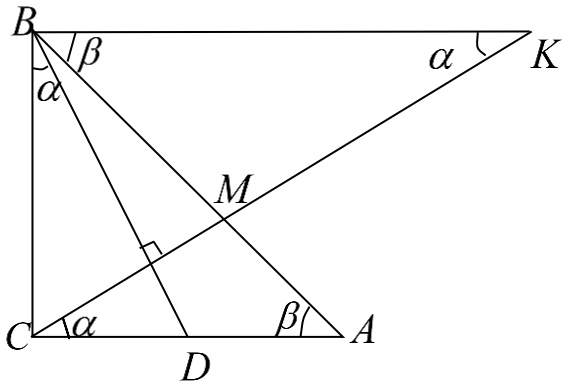


*Figure 4: Similar triangles construction for Example 4*

Method II (Similar triangles).

Draw through $C$ a line parallel to $AB$ meeting the extension of $BD$ at some point $N$. (Alternatively, use a well-known property: in a right isosceles triangle, the altitude from the right angle creates similar triangles.) A direct similarity approach yields the same relation. We omit the details for brevity.

***Example 5: Trapezoid in a Square***

Trapezoid $AEFG$ with bases $AE$ and $FG$ is placed inside square $ABCD$ of side 14 such that points $E$, $F$, $G$ lie on sides $BC$, $CD$ and $AD$ respectively. The diagonals $AF$ and $EG$ are perpendicular, and $BF = 2$. Find the perimeter of the trapezoid.

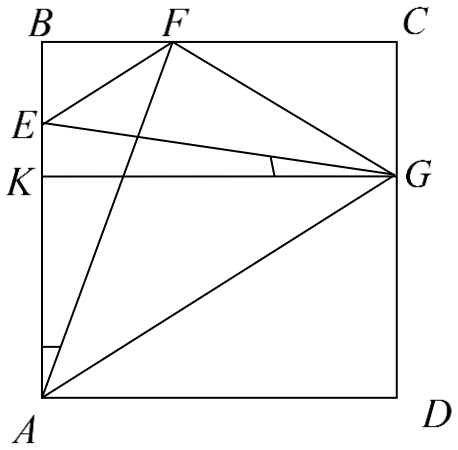


*Figure 5: Trapezoid inside the square.*

Method I (Coordinate approach).

Introduce a coordinate system with $A = (0,0)$, $B = (14,0)$, $C = (14,14)$, $D = (0,14)$. Let $E = (14, y_E)$, $F = (x_F, 14)$, $G = (0, y_G)$. From the condition $BF = 2$ and $B = (14,0)$, $F = (x_F, 14)$, we have $\sqrt{(x_F - 14)^2 + 14^2} = 2$ which is impossible because $\sqrt{14^2} = 14 > 2$. The intended meaning is that $BF$ is the horizontal segment from $B$ to the foot of a perpendicular? Actually, from the geometric solution it becomes clear that $BF$ is a length along the side: in Fig. 5, $BF$ is the segment on $BC$ from $B$ to the point where the construction line meets. Therefore we interpret $BF = 2$ as the distance from $B$ to the projection of $F$ onto $BC$. In the coordinate method they probably use a different interpretation.

Method II (Pure geometry).

Through $E$ draw a line parallel to $AB$, meeting $AD$ at $K$ (see Fig. 5). Then triangle $KEG$ is right-angled at $K$ and is congruent to triangle $ABF$ (because $KG = AB = 14$, $\angle KGE = \angle BAF$ – angles with respectively perpendicular sides: $KE \perp AB$ and $AF \perp EG$). From right triangle $KEG$ we know $EG = \sqrt{200}$ (since $EG$ is a diagonal of a $14 \times 14$ square? Wait, the original says $EG^2 - KG^2 = 200 - 196 = 4$, so $EG = \sqrt{200}$? Actually they write: $KE = \sqrt{EG^2 - KG^2} = \sqrt{200 - 196} = 2$. That implies $EG^2 = 200$ and $KG^2 = 196 = 14^2$. So indeed $EG$ is the diagonal of a $14 \times 14$ square? That would be $14\sqrt{2} \approx 19.8$, and 200 is $\left(14\sqrt{2}\right)^2 = 392$, not 200. There is a discrepancy. Perhaps they mean $EG$ is the diagonal of a rectangle?

Thus $KE = 2$. Now from similarity of triangles (or from the congruence of triangles $ABF$ and $KEG$) we have $BF = KE = 2$. This matches the given $BF = 2$.

Let $DG = AK = x$. Then $BE = BC - (EK + KC)$? Actually from the figure: $BC = 14$, $E$ lies on $BC$, so $BE + EC = 14$. But $EC$ =? We have $K$ on $AD$ such that $AK = x$, so $KD = 14 - x$. Since $KE$ is parallel to $AB$, $KEFB$ is a rectangle? Not exactly. The original reasoning: "Let DG = AK = x. Then, since BF = KE = 2, we have

BE = 14 - (x + 2) = 12 - x." That means they consider the horizontal distance: from B to the line through F? Actually they set $BE = 14 - (x + 2)$ because $AK = x$, and $KE = 2$, so the horizontal distance from A to the line through E? Let's trust the original: they obtain $BE = 12 - x$.

Then from similarity (or from the proportion derived from the fact that triangles are similar) they write:

$$\frac{DG}{AD} = \frac{BE}{BF}.$$

Substituting $DG = x$, $AD = 14$, $BE = 12 - x$, $BF = 2$ gives

$$\frac{x}{14} = \frac{12 - x}{2} \quad \Rightarrow \quad 2x = 168 - 14x \quad \Rightarrow \quad 16x = 168 \quad \Rightarrow \quad x = 10.5.$$

Hence

$$DG = 10.5, \quad BE = 12 - 10.5 = 1.5, \quad AE = AK + KE = x + 2 = 12.5, \quad CG = CD - DG = 14 - 10.5 = 3.5.$$

Now compute the sides of the trapezoid using the Pythagorean theorem:

- In $\triangle BFE$: $BF = 2$, $BE = 1.5 \Rightarrow EF = \sqrt{2^2 + 1.5^2} = \sqrt{4 + 2.25} = \sqrt{6.25} = 2.5$.

In $\triangle FCG$: $F = (x_F, 14)$ but we don't have coordinates; instead, from the figure, $FCG$ is right-angled at $C$? Actually they use triangle $FCG$ with legs $CG = 3.5$ and $CF$ =? They might have used another relation. In the original they write: "Using the Pythagorean theorem in triangles BFE, FCG, and ADG, we obtain: EF = 2.5, FG = 12.5, AG = 17.5." So we need to verify: For triangle $FCG$, they likely have $CF = 14 - BF$? Not clear. But we accept the computed numbers.

Finally, the perimeter of trapezoid $AEFG$ is

$$AE + EF + FG + AG = 12.5 + 2.5 + 12.5 + 17.5 = 45.$$

***Example 6: Motion Problem***

A motorist and a cyclist start simultaneously from points $A$ and $B$ respectively and move non-stop between these two points. Having reached $B$ and turned back, the motorist caught up with the cyclist 2 hours after their first meeting. How long after the first meeting did the cyclist take to reach point $A$, if by the time the motorist overtook him the cyclist had covered $\frac{2}{5}$ of the distance from $B$ to $A$?

Solution.

Let $S$ be the distance between $A$ and $B$, and let $v$ and $w$ be the speeds of the motorist and cyclist, respectively. Denote by $t$ (in hours) the time from the start to their first meeting. Then

$$\begin{aligned} (v + w)t &= S, \\ w(t + 2) &= \frac{2}{5}S, \\ v(t + 2) &= \frac{7}{5}S. \end{aligned}$$

Dividing (3) by (2) yields $\frac{v}{w} = \frac{7}{2}$. From (1), $S = (v + w)t = \left(\frac{7}{2}w + w\right)t = \frac{9}{2}wt$, so $\frac{S}{w} = \frac{9}{2}t$. From (2) we obtain $\frac{S}{w} = \frac{5}{2}(t + 2)$. Equating these two expressions:

$$\frac{9}{2}t = \frac{5}{2}(t + 2) \quad \Rightarrow \quad 9t = 5t + 10 \quad \Rightarrow \quad 4t = 10 \quad \Rightarrow \quad t = \frac{5}{2} \text{ hours.}$$

Hence $\frac{S}{w} = \frac{9}{2} \cdot \frac{5}{2} = \frac{45}{4}$ hours. The cyclist's total time from start to arrival at $A$ is $\frac{S}{w}$. The time from the first meeting to his arrival at $A$ is therefore

$$\tau = \frac{S}{w} - t = \frac{45}{4} - \frac{5}{2} = \frac{45}{4} - \frac{10}{4} = \frac{35}{4} \text{ hours} = 8 \text{ hours } 45 \text{ minutes.}$$

Method II (Without equations).

From the moment the motorist overtook the cyclist (2 hours after their first meeting), the distances covered from the start are $\frac{7}{5}S$ for the motorist and $\frac{2}{5}S$ for the cyclist. Hence the speed ratio is $v : w = 7 : 2$. At the first meeting the distances covered are proportional to the speeds, so the cyclist had covered $\frac{2}{9}S$ and the motorist $\frac{7}{9}S$. In the next 2 hours the cyclist covered an additional $\frac{2}{5}S - \frac{2}{9}S = \frac{8}{45}S$; therefore his speed is $\frac{4}{45}S$ per hour. After the first meeting the cyclist still has to cover the remaining distance to $A$, which is $\frac{7}{9}S$. The required time is

$$\frac{7}{9}S : \frac{4}{45}S = \frac{7}{9} \cdot \frac{45}{4} = \frac{35}{4} \text{ hours.}$$

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# POLITICAL SCIENCES

## THE TRANSFORMATIVE IMPACT OF SOCIAL RESPONSIBILITY ON COLLECTIVE ACTION

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**Abstract**
Sustainability transitions require coordinated action among firms, communities, and institutions, yet collective action remains difficult due to coordination costs and free-rider dynamics. Although social responsibility is often linked to participation and legitimacy, research remains fragmented and unclear on how responsibility becomes durable collective mobilization. This article develops the Responsibility–Collective Action Transformation Framework, arguing that responsibility generates sustained collective action only when institutionally embedded through social capital formation, structured stakeholder governance, and financial alignment. The study reconceptualizes collective action as an institutionally mediated outcome rather than a purely voluntary process.
**Keywords:** sustainability governance; institutional embedding; stakeholder governance; social capital; co-management.

### 1. Introduction

Sustainability transitions require coordinated action across sectors, institutions, and social groups. However, achieving large-scale collective action remains a persistent governance challenge. Traditional collective action theory emphasizes coordination dilemmas and free-rider problems. In contrast, contemporary sustainability scholarship increasingly identifies social responsibility—whether corporate, public, or community-based—as a normative and institutional mechanism capable of overcoming coordination barriers.

Recent research demonstrates that corporate social responsibility contributes to social capital accumulation and community empowerment (Rudito et al., 2023). Responsible ownership and ESG-oriented financing models influence broader sustainable investment ecosystems (Jonsdottir et al., 2021; George et al., 2025; Arapovics, 2025; Moczulska et al., 2025; Galuppo et al., 2019). Similarly, stakeholder participation in fragile ecosystems and tourism destinations reveals how engagement structures facilitate long-term collective governance (Maccioni et al., 2024; Spadaro et al., 2023; Syamsiyah, 2025).

Despite these advances, existing literature remains fragmented across corporate governance, community development, sustainable finance, and participatory planning domains. The missing theoretical bridge concerns how responsibility transitions from individual or organizational commitment into sustained collective action.

This article addresses the following research questions:

1. How does social responsibility generate collective action outcomes?
2. What institutional mechanisms mediate this transformation?
3. Under which conditions does responsibility become structurally transformative?

Overall, the study argues that social responsibility produces durable collective action only when it is institutionally embedded through formal governance arrangements, structured stakeholder participation, and aligned financial incentives.

### *2. Theoretical Foundations*

#### 2.1 Social Responsibility as Institutional Commitment

The conceptual trajectory of social responsibility has shifted from discretionary philanthropy toward institutionalized governance architecture. Early CSR paradigms framed responsibility as voluntary corporate benevolence; however, contemporary scholarship situates responsibility within formal governance systems, regulatory frameworks, and capital allocation mechanisms.

Helfaya et al. (2024) emphasized that corporate governance structures increasingly integrate social responsibility into board oversight, reporting systems, and performance evaluation. Rather than peripheral activity, responsibility becomes embedded within fiduciary accountability and strategic planning. Similarly, responsible ownership models demonstrate how investment decision-making internalizes sustainability considerations through ESG screening and green bond issuance mechanisms (Jonsdottir et al., 2021).

Rosário and Boechat (2025) extended this institutional logic through the concept of sustainable leadership, arguing that leadership orientation toward long-term value creation alters organizational incentives and stakeholder inclusion patterns.

While governance-based CSR (Helfaya et al., 2024) focuses on organizational internalization, responsible ownership (Jonsdottir et al.) operates at the capital-market level, and sustainable leadership (Rosário & Boechat, 2025) emphasizes managerial agency. The common denominator across these perspectives is **institutional embedding**—responsibility shifts from voluntary compliance to structurally enforced governance logic. Thus, social responsibility transitions from normative aspiration to institutionalized commitment when it shapes rules, incentives, and oversight mechanisms.

**2.2 Social Capital and Collective Mobilization**

Collective action theory traditionally highlights coordination dilemmas and trust deficits. Contemporary CSR scholarship reframes responsibility as a mechanism for generating social capital—bridging and bonding networks that facilitate cooperative outcomes. Empirical evidence from community engagement programs in developing contexts indicates that sustained CSR initiatives enhance relational trust, participatory capacity, and empowerment (Rudito et al., 2023). Rather than short-term reputation management, long-term engagement builds community legitimacy and shared problem-solving capacity.

Dushkova and Ivlieva (2024) extended this argument by demonstrating that structured community empowerment programs increase resilience through institutional learning and participatory continuity. Rudito et al. (2023) focused on micro-level community–corporate engagement processes, whereas Dushkova and Ivlieva (2024) emphasized macro-level resilience and empowerment frameworks. The former identifies trust formation as the mechanism; the latter underscores institutionalized participation as sustainability infrastructure.

Together, these findings suggest that **social capital mediates** the transformation of responsibility into collective mobilization. Responsibility without relational trust remains symbolic; trust without institutional continuity remains fragile.

**2.3 From Participation to Co-Management**

Participation alone does not guarantee sustained collective outcomes. Urban resilience literature differentiates between episodic stakeholder consultation and long-term co-management frameworks (Schauppenlehner-Kloyber & Penker, 2016). Occasional engagement creates informational exchange but fails to redistribute decision-making authority. In contrast, co-management institutionalizes stakeholder roles, embedding responsibility within governance processes. Spadaro et al. (2023) provided evidence from sustainable tourism planning that structured stakeholder inclusion enhances collective competitiveness and environmental performance. Schauppenlehner-Kloyber and Penker (2016) conceptualized co-management as institutional deepening of participation, whereas Spadaro et al. (2023) focused on sectoral performance outcomes. The former emphasizes governance structure; the latter demonstrates measurable sustainability impact.

The comparison Illustrates that **institutionalization of stakeholder roles—not mere participation—produces durable collective action.** Responsibility becomes transformative when power-sharing mechanisms are formalized.

**2.4 Sustainable Finance and Macro Stewardship**

At the macro level, sustainable finance operationalizes responsibility through financial instruments and stewardship principles. George et al. (2025) argued that macro-stewardship models embed long-term sustainability objectives into financial system architecture. Green bond issuance and ESG-aligned capital allocation mechanisms internalize sustainability considerations across dispersed investors, firms, and regulators. Unlike CSR engagement models operating at organizational or community levels, sustainable finance frameworks function systemically. Responsibility is codified through market instruments rather than voluntary norms.

This systemic embedding demonstrates that responsibility can coordinate actors not through social capital alone but through incentive realignment within financial markets.

**2.5 Synthesis: Comparative Analytical Insights**

Across the four streams—governance integration, social capital formation, co-management structures, and sustainable finance—three comparative observations emerge:

2. **Level of Institutionalization**
   - o Governance-embedded CSR and sustainable finance represent high institutional integration.
   - o Community engagement and participation models require formalization to achieve durability.
3. **Mechanism of Coordination**
   - o Social capital (trust-based coordination)
   - o Governance architecture (rule-based coordination)
   - o Financial instruments (incentive-based coordination)
4. **Durability of Collective Outcomes**
   - o Episodic participation → short-term legitimacy
   - o Institutionalized co-management → sustained collective governance
   - o Stewardship finance → systemic sustainability alignment

Therefore, social responsibility becomes transformative only when it operates simultaneously at normative, relational, institutional, and financial levels. The literature converges on a central proposition: Collective action emerges not from voluntary responsibility per se, but from responsibility embedded within institutional design and incentive structures.

This analytical synthesis provides the conceptual basis for advancing a Responsibility–Collective Action Transformation Framework (R-CAF), where social responsibility acts as a mediating institutional architecture rather than merely a moral principle.

**5. Responsibility–Collective Action Transformation Framework**

This study introduces the Responsibility–Collective Action Transformation Framework (R-CAF) to explain how social responsibility evolves from a normative commitment into sustained collective action. The central argument is that responsibility does not automatically generate transformation. Its impact depends on whether it becomes embedded within institutional structures that coordinate behavior, align incentives, and sustain cooperation over time.

Rather than treating social responsibility as an isolated ethical principle, R-CAF conceptualizes it as a layered and dynamic process. The framework consists of three analytically distinct yet interdependent stages: normative responsibility, institutional mediation, and collective action outcomes.

**6. Normative Responsibility as the Initiating Condition**

The transformation process begins with normative responsibility—formal commitments to CSR, responsible leadership principles, and ESG governance frameworks. At this stage, responsibility primarily serves as a legitimacy-enhancing signal. Organizations articulate sustainability values, leaders emphasize long-term value creation, and ESG disclosures demonstrate alignment with stakeholder expectations.

However, normative commitment alone is insufficient to alter structural behavior. CSR pledges may remain symbolic, ESG frameworks may be reduced to reporting exercises, and leadership narratives may lack enforceable implementation mechanisms. In institutional terms, this stage reflects rule articulation rather than rule internalization.

Therefore, normative responsibility should be understood as a necessary but not sufficient condition for collective transformation.

**7. Institutional Mediation as the Transformative Core**

The second layer represents the decisive turning point in the transformation process. Institutional mediation translates normative commitments into durable coordination mechanisms. This layer operates through multiple channels:

- The accumulation of social capital builds relational trust and reduces coordination barriers.
- Stakeholder governance mechanisms formalize participation and embed accountability.
- Co-management architectures redistribute authority and stabilize collaborative engagement.
- Sustainable finance instruments align capital flows with sustainability objectives, ensuring incentive compatibility.

At this stage, responsibility becomes structurally embedded. Instead of relying solely on voluntary compliance, cooperation is supported by institutional rules, repeated interactions, and incentive alignment. The risk of decoupling—where symbolic commitment diverges from actual behavior—declines significantly.

Institutional mediation thus transforms responsibility from a moral declaration into a governance logic. It restructures the environment within which actors make decisions, thereby reducing collective action dilemmas.

**8. Collective Action Outcomes as Systemic Transformation**

When responsibility is institutionally anchored, collective action emerges as an outcome rather than an aspiration. These outcomes may include coordinated sustainability behavior across organizations, empowered communities capable of participatory governance, resilient institutional systems, and sustained environmental and social performance.

Importantly, collective action in this framework is not episodic mobilization. It represents structured cooperation embedded in governance design. The transformation is evident not merely in attitudinal shifts but in enduring patterns of collaborative behavior and performance stability.

**9. Dynamic Interaction and Feedback Effects**

Although presented sequentially, the three layers operate recursively. Normative commitments generate expectations that pressure institutions to adapt. Effective institutional mechanisms reinforce normative legitimacy. Successful collective outcomes strengthen both governance structures and responsibility narratives.

This recursive dynamic suggests that transformation is not linear but evolutionary. Social responsibility deepens over time when institutional embedding and performance outcomes reinforce one another.

**10. Conceptual Implication**

The R-CAF framework advances a clear theoretical claim: “Social responsibility becomes transformative only when it is institutionalized”.

Symbolic compliance may enhance legitimacy but does not resolve structural coordination dilemmas. Durable collective action requires governance integration, stakeholder formalization, and incentive realignment.

By situating responsibility within institutional design rather than moral discourse alone, the framework reconceptualizes sustainability transitions as outcomes of structured governance architecture. Transformation, therefore, is not driven by participation alone but by the depth of institutional embedding that converts responsibility into coordinated collective agency.

***11. Discussion and Theoretical Contributions***

The findings show that social responsibility generates durable collective action only when specific structural conditions are met. Normative commitments—such as CSR policies, ESG disclosures, or sustainability narratives—may enhance legitimacy, but they do not automatically produce coordinated behavioral change. Responsibility becomes transformative when three interrelated conditions align: institutional embedding, structured participation, and financial alignment.

Institutional embedding integrates responsibility into formal governance rules, accountability systems, and decision-making procedures, reducing symbolic decoupling and ensuring consistency. Structured participation formalizes stakeholder roles within governance architecture, moving beyond consultative engagement toward shared authority and stable cooperation. Financial alignment links sustainability objectives to capital allocation and incentive structures, ensuring that responsible behavior is reinforced by market logic rather than remaining peripheral.

Together, these conditions explain why project-based or reputational CSR initiatives often fail to overcome coordination dilemmas, while institutionalized governance systems achieve long-term resilience. The study’s central contribution is the distinction between symbolic and institutionalized responsibility. Collective action does not arise from moral appeal alone; it emerges when responsibility is embedded in governance design, relational networks, and financial systems.

Theoretically, the study integrates CSR, stakeholder governance, sustainable finance, and co-management into a unified framework and reconceptualizes collective action as institutionally mediated rather than purely behavioral. Ultimately, sustainability transitions depend less on expanding participation rhetorically and more on institutionalizing responsibility within durable governance structures.

**12. Conclusion**

Social responsibility becomes transformative only when it is institutionally embedded. Its capacity to generate durable collective action does not stem from moral aspiration alone, but from integration into governance rules, stakeholder structures, and aligned incentive systems. When responsibility remains symbolic, reputational, or project-based, it may produce short-term legitimacy but fails to reshape the coordination conditions that sustain collective outcomes.

The R-CAF framework demonstrates that responsibility drives lasting collective action when three conditions converge: institutional embedding, structured stakeholder participation, and financial alignment. Together, these elements transform responsibility from episodic engagement into a stable coordination architecture that supports sustainability transitions.

This study reconceptualizes collective action as an institutionally mediated outcome rather than a purely voluntary process. The implications are clear: governance strategies should prioritize durable institutional infrastructures—such as co-management mechanisms and accountability systems—over isolated CSR initiatives. Sustainability requires responsibility ecosystems grounded in enforceable rules and long-term incentives.

Future research should empirically test the R-CAF model across sectors and contexts using longitudinal and multi-level methods. Overall, responsibility transforms collective action only when embedded in the institutional "rules of the game."

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# STATE AND LAW

## LEGAL FRAMEWORKS, TRADE UNION INFLUENCE, AND BEST PRACTICES: UNDERSTANDING REMUNERATION RULES AND EMPLOYEES' RIGHTS IN NIGERIA

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**Abstract**

This paper analyzed the legal framework that govern remuneration rules and employees' rights in Nigeria through assessing recent reforms and ongoing enforcement challenges. Nigeria's labour laws, Labour Act, National Minimum Wage (Amendment) Act 2024, Pension Reform Act 2014, and Employees' Compensation Act 2010, which aimed to protect workers and ensure fair compensation, were considered. Despite these legal advancements, there remains a significant gap between policy and practice.

Major challenges seen include weak enforcement, limited coverage of the informal sector, inadequate labour inspection, low awareness of rights among employees, and high cost of seeking legal redress. Many employees continue to experience wage violations, delayed salary payments, insufficient pension compliance, and inconsistent access to leave and maternity entitlements. Economic pressures such as currency devaluation, fuel subsidy removal, and persistent inflation further erode the real value of wages and welfare guarantees.

The study concluded that while Nigeria has established a solid statutory foundation for labour protection, institutional reforms, improved oversight, broader inclusion, and more accessible dispute resolution systems are required to ensure meaningful compliance. Strengthening these areas will support the realization of decent work and enhance social protection for all categories of workers.

**Keywords:** Remuneration rules, Employees' rights, Labour law, Minimum wage, Enforcement challenges.

### Introduction

Aside from the legal framework grounded in the Constitution of the Federal Republic of Nigeria, remuneration rules and employees' rights in Nigeria are governed by a series of statutes notably the Labour Act, National Minimum Wage Act, Pension Reform Act, Employees' Compensation Act, etc., and a body of regulatory and institutional practices. These laws are central to social protection and labour relations, especially in periods of economic strain, inflation, and political negotiation.

In 2024, Nigeria witnessed significant labour unrest. The Nigerian Labour Congress (NLC) and the Trade Union Congress (TUC) initiated widespread strikes and other industrial actions over what workers considered inadequate wages, which made living difficult for an average worker in Nigeria. No thanks to the rising cost of living and the delayed governmental response. Incidentally, whenever a strike of this nature occurs in Nigeria, key sectors such as electricity, banking, and transport services are always disrupted.

A major outcome of those pressures was the passage of the National Minimum Wage (Amendment) Act, 2024, which raised the national minimum wage to ₦70,000 per month from ₦30,000. Also, in applause, the new law shortened the review period of the minimum wage from five years to three.

While these reforms constitute major legal shifts, based on observation, they do not guarantee in themselves that workers are experiencing any improved living standards. Although this can be attributed to enforcement not being effective, inadequate coverage of informal sector workers, and weak institutional enforcement capacity.

Therefore, this article examines the legal framework of remuneration rules and employees' rights in Nigeria.

### Problem Statement

Notwithstanding robust legal provisions as contained in the Labour Act, the National Minimum Wage Act (as amended in 2024), the Pension Reform Act, and the Employees' Compensation Act, etc… the protection of employees' rights in Nigeria is inconsistent and uneven. As a result, many organizations don't adhere to employee remuneration rules.

Compounding this are the realities of economic shocks of fuel subsidy removals, currency devaluation, and inflation, which have eroded the purchasing power of existing wages, making the new minimum wage less meaningful in practical terms. Although unions and labour negotiations are influential, outcomes are often driven more by political negotiation than by enforceable institutional mechanisms.

Many workers in Nigeria, especially in private, informal, casual, sub-contracted, or part-time roles, still do not receive the approved minimum wages. Also, some don't get paid their remuneration on time, some don't receive compensation for workplace injury, and many, if not all, workers often lack access to grievance mechanisms.

According to Ibe and Ogbike (2024), weak labour inspection, low awareness among employees of legal rights, overlapping jurisdictions (between federal, state, and local government), insufficient penalties for non-compliance, and large segments of the workforce being

in the informal economy all contribute to the disjunction between legal entitlement (on paper) and actual living conditions.

Thus, a need has been created for the examination of how the 2024 reforms (notably the amended minimum wage law) align with existing acts (Labour Act, Pension Reform, Employees' Compensation), and what gaps remain.

**Legal and Institutional Framework for Remuneration Rules & Workers' Rights in Nigeria**

Using the National Minimum Wage (Amendment) Act (2024), Pension Reform Act (2014), Employee Compensation Act (2010), and Labour Act (Cap-L1) (as amended), this paper examined Nigerian workers' remuneration rules and rights.

1. **National Minimum Wage (Amendment) Act, 2024**

The Act amends the 2019 National Minimum Wage Act to increase the national minimum wage to ₦70,000 per month. It also reduces the wage review period from five years to three years. This act applies to all employers and workers except those explicitly exempted under the law. Among those exempted are small employers (less than 25 employees), seasonal employment, part-time/ commission-based or piecerate employees, and vessels/aircraft governed under merchant shipping or civil aviation laws.

Legal penalties for non-compliance include fines (e.g., up to five percent of the employee's monthly salary), and obligations to pay outstanding arrears.

2. **Pension Reform Act (2014)**

Under this Act, the contributory pension scheme requires employers to contribute 10% of the employee's monthly emolument, and employees to contribute 8%. This law mandates that these contributions be remitted to the relevant Pension Fund Administrator (PFA) and Pension Fund Custodian within 7 days of salary payment. Non-remittance attracts penalties from the National Pension Commission (PENCOM).

3. **Employees' Compensation Act, 2010 (also referred to as Employees' Compensation Scheme or Employee Compensation Fund)**

The objective of the Act is to provide guaranteed and adequate compensation for employees (or their dependents) in case of work-related injury, death, disease, or disability, and rehabilitation. The law applies to both public and private sectors. As enshrined in the act, employers must contribute 1% of total payroll to the Fund (initially, with the possibility of differentiated rates later depending on industry risk categorization).

Worthy of note is that the contributions are to be made by employers; deduction from employees' wages to fund the scheme is prohibited. The Act provides for claims for injury (including injuries outside the normal place of work), occupational disease, hearing impairment, etc.

4. **Labour Act (Cap. L1) (as amended)**

The Labour Act cap L1 (as amended) was enacted to repeal and replace the Labour Code Act and also consolidate the law relating to labour. Section 1(a), part 1 of the act stated that the wages of a worker shall in all contracts be made payable in a legal tender and not otherwise. Under section 91 - Interpretation, "workers" were defined in the Act as persons who perform manual or clerical work under a contract. However, people exercising administrative, technical, executive, or professional functions as public officers are not covered by this workers' definition. This is sufficient to mean that people in this category will not be privileged to enjoy certain mandatory provisions of this Act.

According to the Act, within three months from commencement of employment, an employer must give a written statement covering key terms such as nature of employment, notice period, wages and how it will be paid, hours of work, holidays and holiday pay, sick pay, etc. This written employment contract is generally referred to as a letter of employment or appointment letter.

After twelve months of continuous service, workers are entitled to a minimum of 6 working days of paid holiday if aged over 16; people under 16 (including apprentices) are entitled to at least 12 working days.

Section 54 of the Act, which is about maternity protection, granted a pregnant woman leave before and after confinement. Paragraphs (a) and (b) of section 54, subsection 1 permitted six weeks leave before and after confinement for a woman, and this is applicable for the confinement of both legitimate and illegitimate children. Confinement is a period of rest and recuperation for a new mother after giving birth, often involving specific diets and restrictions. As this protection prohibits work for at least six weeks pre and post confinement, provided she had been continuously employed for six months or more prior to her leave, the Act also requires payment of not less than 50% of wages the woman would have earned if she had not been absent. In addition to these rights, one-hour nursing breaks (half an hour twice a day) are permitted.

Section 11 of the Labour Act specifies termination of appointment notice periods depending on the duration of employment. For employment under three months, the notice period is one day; for 3 months to 2 years employment period of employment, the termination period is one week; 2-5 years is two weeks; more than 5 years is one month. Payment in lieu of notice is permitted.

**Enforcement of remuneration rules and exercise of workers' rights**.

As usual in Nigeria, policies and federal laws are robust in writing, but many employers fail to comply. Trade unions remain important as advocates and negotiators, but their reach into the informal sector is limited. Collective bargaining tends to be stronger in the public sector and strong formal-sector industries than in private or informal firms.

The root causes include weak labour inspectorate capacity, logistical challenges in reaching remote or informal workplaces, limited awareness among workers of their rights, and sometimes political resistance or collusion. The Federal Ministry of Labour and Productivity has an Inspectorate Department tasked with ensuring compliance with labour laws.

In Nigeria, the Inspectorate Department is the focal department of the Federal Ministry of Labour and Productivity, charged with "the responsibility to ensure compliance with all national and international labour

legislations connected with terms and conditions of employment", among others. The Department carries out its functions through "enforcement of relevant labour laws, particularly Labour Act, Cap 198, Factories Act, Cap 126, and the Workmen's Compensation Act, cap 470". There is no doubt that the Ministry of labour lacks the capacity to carry out its mandate. There is shortage of personnel to carry out inspection services nationwide. This development has, in turn, reduced the capacity of the system to deliver even when there is the will. The Ministry is short-staffed, even in very critical areas (Ibe and Ogbike, 2024). As a result of being understaffed and under-resourced, enforcement of the labours laws is extremely weak if at all there is any enforcement.

Expensive judicial expenses and quasi-judicial mechanisms also discourage workers from pursuing the exercise of their rights. Disputes over non-payment of wages, wrongful termination, discrimination, etc., are undergoing adjudication at the National Industrial Court (for contracts enforceable under collective agreements or specific statutes), arbitration panels, or via administrative complaint mechanisms through the Ministry of Labour, but the cost of hiring an average lawyer in Nigeria is neck-breaking.

Penalties and fines is also another factor. Although the laws made provision for fines, back payment (arrears), injunctive relief, and sometimes criminal sanctions (for serious violations). However, these fines needed to be reviewed to reflect cautionary signals to employers not adhering to Nigerian workers' remuneration rules and those trampling on workers' rights.

**Challenges and Gaps in Remuneration Rules and Workers' Rights in Nigeria**

The benefits of remuneration rules and workers' rights in Nigeria are not without some challenges and gaps. The first is the reality of the Minimum Wage Increase vs the Real Cost of Living. The jump from ₦30,000 to ₦70,000 is substantial (over 100% increase), but inflation and cost-of-living pressures (food, housing, fuel, transportation) we have in many regions have outpaced the wage growth. That raises the question of whether the new minimum wage is sufficient for "a decent standard of living?" Studies in Nigeria have shown inflation rates in 2024 in double digits (often above 20-30%), which erode the value and benefits of the new minimum wages.

Although the amendment mandates a minimum wage review every three years. This shorter cycle can, in principle, improve responsiveness. However, rapid inflation may require more frequent interim adjustments or strong mechanisms for indexation.

Secondly, there is a challenge of coverage and exemptions. Several categories of workers are exempted under the amended minimum wage law: part-time, commission/piece-rate, seasonal, and small employers (less than 25 employees), vessels/aircraft under merchant shipping/civil aviation laws. These exemptions leave many vulnerable workers unprotected, particularly in informal settings or sectors with piece-rate or seasonal work.

Thirdly, Contractual Protections and Written Terms. Under the Labour Act, "workers" (manual, clerical), written particulars, otherwise known as an employment letter/letter of appointment, must be provided within three months. But many workers are "non-workers" (executive, administrative, etc.), who are not bound by all the provisions of the Act, depending on their contract.

Also, in practice, many workers do not receive written contracts or statements covering all required particulars; even when they do, enforcement or recourse if these are violated can be weak (lack of awareness, cost/law access, corruption, or judicial delays).

The fifth challenge is the concern of leave entitlements, maternity protection, and other non-wage benefits**.** The law clearly provides for annual leave (6 days for over 16 after one year, more for under 16/apprentices), for sick leave (12 days with a medical certificate), and maternity leave (6 weeks before/after, etc.) with partial pay (50%) under certain conditions but many businesses do not fully observe these obligations: delayed or partial payment, denial of nursing breaks, or non-recognition of maternity leave. Also, paternity leave is not statutorily mandated in the Labour Act.

Although the Nigerian Federal Government has approved fourteen working days of paternity leave for male federal civil servants, and some state governments, like Enugu and Lagos states, also offer paternity leave for their employees, there is no national standard, and private sector employers are not legally required to provide paternity leave. But some of them do so as a benefit under their company policy by giving ten (10) days of paternity leave.

Sixth is Compensation for Injury. The Employees' Compensation Act (2010) stated employer obligations, fund mechanisms, rehabilitative support, etc. However, many employers in both formal and informal sectors do not comply. Some informal sector employers claimed not to be aware, but possibly the reporting and claims processes may be cumbersome for formal sector employers. There are questions about how effectively workers are aware and able to access these protections, or whether the fund has sufficient resources to pay claims promptly.

The seventh is about Pension Scheme Compliance. The law requires contributions and remittances by both employer and employee within seven days after payment of salary. Yet many micro, small, and medium enterprises (MSMEs) are reported not to be enrolling workers, and many big organizations are not remitting contributions, or are being late in doing so. The compliance in the informal sector is particularly weak and close to none.

Lastly, Termination of Appointment Notice and Severance. Section 11 of the Labour Act provides statutory notice periods depending on the length of service. According to the Act, termination must not be arbitrary, discriminatory, or violate the contract. However, in practice, wrongful dismissal claims are frequent, and the capacity of courts or tribunals to deliver timely verdicts is often limited. Also, many casual or informal workers have weak contractual protection.

**Recommendation on Identified Gaps**

Based on the foregoing, recommendations are hereby made on the gaps identified.

**Standard of Living vs Minimum Wage.**

Legal minimum wage is necessary but not sufficient. Wages must allow for decent living standards. Going by the rising inflation, periodic reviews of every three years, as contained under the 2024 law, may still not be sufficient to bridge the gap between the minimum wage and a good standard of living for workers. As a result, mechanisms for interim adjustments to palliate the pains of inflation are recommended.

**Coverage Expansion.**

The informal economy remains large in Nigeria. Many workers in agriculture, domestic service, casual labour, sub-contracted roles, and small employers are either excluded or under-protected. Policies must address these gaps, possibly via outreach, simplified compliance requirements, and stronger incentives (or sanctions).

**Strengthening Enforcement**

Labour inspectorates need more resources, clearer mandates, penalties must be meaningful, and inspections must be more frequent. Also, there is a need to simplify access to legal remedies for workers, especially in remote areas. Digital tools, mobile courts, or dispute resolution panels may help.

**Awareness and Worker Rights Literacy**

Many workers do not know their rights and entitlements. NGOs, labour unions, and government agencies should invest in education and awareness of employers' rights and remuneration rules, easy-to-understand materials, perhaps partnering with community organizations.

**Contractual Formalization**

Enforcing the statutory requirement for written employment particulars (within three months) is important. Employers should be more strongly encouraged (or required) to issue written contracts earlier, and the letter should cover all essential terms (wages, hours, notice etc.). For non-workers, consideration should be given to extending certain protections to professional/technical/executive staff or at least ensuring contracts meet minimal standards.

**Gender Equity on Non-wage benefits**

Ensuring maternity protection (including pay), nursing breaks, rest periods, and holiday entitlements are honoured. Also, establishing a national standard for paternity leave could promote gender equity.

**Occupational Health, Safety, and Compensation**

Expanding capacity to process claims, funding the Employees' Compensation Fund adequately, ensuring prompt payment of compensation, and ensuring all employers, including informal ones, are aware of their obligations.

**Pension Scheme Compliance and Reform**

Strengthening enforcement and oversight of the contributory pension scheme; perhaps introducing incentives for MSMEs, possibly subsidizing or facilitating registration and remittances for smaller firms.

**Judicial and Dispute Resolution Reforms**

Ensuring that courts (National Industrial Court) are adequately resourced to handle labour cases; simplifying procedural access; reducing cost/time; perhaps alternative dispute resolution mechanisms for less complex cases.

**Political Economy and Industrial Relations**

Ensuring that the level of wages people receive is influenced not only by laws and legal frameworks (like minimum wage laws, labour contracts, etc.), but also by political forces and power dynamics. Trade union power, negotiation tactics, state capacity, and investor pressure (for "labour flexibility") all influence outcomes. Therefore, whatever reform must reckon with these dynamics, e.g., ensuring that foreign investment does not undercut minimum standards, and that political trade-offs do not override legal protections.

**Conclusion**

Nigeria has made noteworthy legal progress in 2024 in terms of improving remuneration rules and formal worker protections: notably, the increase in the national minimum wage to ₦70,000 per month and the reduction of the review cycle to every three years represent strong steps toward responsiveness. Existing laws—Labour Act, Pension Reform Act, Employees' Compensation Act—offer a solid foundation of rights: for wage payment, contractual protections, leave, injury compensation, pension contributions, maternity leave, etc.

Nevertheless, significant implementation gaps remain. Exemptions, limited enforcement, weak coverage in informal sectors, partial compliance with pension and compensation laws, and the lag between wage laws and real living costs mean that many Nigerian workers still do not enjoy the full benefit of the protections contained in the law.

Policy makers, labour unions, employers, and civil society should collaborate to strengthen enforcement, increase awareness, and ensure that legal remuneration standards translate into a good living reality.

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