ISSN: 3106-065X
e-ISSN: 3104-4735

Journal of
Technology Studies

International Scientific Journal

Journal of
TECHNOLOGY STUDIES

International Scientific Journal

Volume: 3 Issue: 4

2026

International Indexing













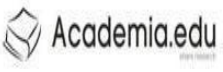





© The Author(s) 2026. This is an open access journal under the CC BY-NC 4.0 license.

Founder

Researcher Mubariz HUSEYINOV, Azerbaijan Science Center / Azerbaijan
https://orcid.org/0000-0002-5274-0356
mubariz0868@gmail.com

Editor-in-Chief

Prof. Dr. Fakhraddin HABIBOV, Azerbaijan Construction and Architecture Scientific Research Institute / Azerbaijan
https://orcid.org/0009-0007-9598-8347
farchad@yandex.ru

Editors

Prof. Dr. Fakhraddin YUSUBOV, Azerbaijan Technical University / Azerbaijan
https://orcid.org/0000-0002-3496-8947

Prof. Dr. Bulent CHAKMAK, Erzurum Technical University / Türkiye
https://orcid.org/0000-0002-9939-4809

Prof. Dr. Fariz AMIRLI, Institute of Polymer Materials / Azerbaijan
https://orcid.org/0000-0002-9095-2982

Assoc. Prof. Dr. Sanjarbek MADAMINOV, Urgench State University named after Abu Rayhan Biruni / Uzbekistan
https://orcid.org/0000-0002-8408-5771

Assistant editor

Researcher Nigar BOURCHICH, Azerbaijan Science Center / Azerbaijan
https://orcid.org/0009-0005-9890-8926

Language editor

Assoc. Prof. Dr. Nigar SEYIDOVA, Baku State University / Azerbaijan

EDITORIAL BOARD

Prof. Dr. Aminagha SADIGOV, Sumgait State University / Azerbaijan
Prof. Dr. Khalil KALANTAR, Tohoku University / Japan
Prof. Dr. Valery LISENKO, All-Russian Metrological Service Research Institute / Russia
Assoc. Prof. Dr. Elnur ABBASOV, Azerbaijan State Maritime Academy / Azerbaijan
Assoc. Prof. Dr. Elov BOTIR, Tashkent State University of Uzbek Language and Literature named after A.Navai / Uzbekistan
Assoc. Prof. Dr. Elshan SULTANOV, Azerbaijan State Maritime Academy / Azerbaijan
Assoc. Prof. Dr. Ilkhombek KHOLIDDINOV, Ferghana Polytechnic Institute / Uzbekistan

Journal of Technology Studies
November 2026, Volume: 3, Issue: 4, pp. 5−9
DOI: https://doi.org/10.36719/3104-4735/6/5-9

Design and Implementation of Smart Monitoring Systems Based on IoT Sensor Devices

Ceyran Aghamaliyeva[1*], and Emin Janiyev[2]

Abstract. *This article examines the technological principles of designing and implementing smart monitoring systems based on sensor technologies and Internet of Things (IoT) platforms. The main objective is to analyze the functional architecture of IoT-based monitoring systems designed for automated measurement, collection, transmission, processing, and presentation of physical and environmental parameters. The study considers sensor nodes, communication protocols, data processing mechanisms, the integration of cloud and edge computing technologies, and information security requirements. Based on a systematic and comparative analysis, a generalized architecture consisting of sensing, communication, data processing, and application layers is presented. The potential applications of these systems in industry, agriculture, environmental monitoring, and smart city infrastructure are also discussed. The analysis indicates that sensor-based IoT systems enable real-time data acquisition, more efficient resource utilization, and improved information support for management decisions. At the same time, system reliability depends on sensor accuracy, communication stability, data security, and energy efficiency. The article also identifies technical evaluation criteria for future applied research, including measurement error, transmission delay, packet loss, energy consumption, and system availability. The study is conceptual and literature-based; no experimental prototype results are claimed.*

Keywords: *Internet of Things, IoT, sensor technologies, smart monitoring, data processing, edge computing, cloud technologies, digital management*

Introduction

In the modern era, the rapid advancement of information and communication technologies has led to the widespread implementation of automated control systems in manufacturing, agriculture, energy, environmental protection, and urban infrastructure sectors (Sadiqli, 2024). The deepening processes of digital transformation necessitate continuous monitoring of the operational status of various objects, prompt data acquisition, and informed decision-making based on these data. The foundation of this concept relies on the interconnectedness of networked devices (Ashton, 2009). The Internet of Things (IoT) is a complex technological platform that enables physical objects, sensors, measuring devices, and other electronic equipment to interconnect, exchange data, and automate specific functions via communication networks (Borgia, 2014). The primary feature of IoT systems is the conversion of raw data gathered from the physical environment into digital format, its transmission, and subsequent analytical processing.

[1]Azerbaijan State Oil and Industry Academy, PhD in Technology, Baku, Azerbaijan
[2]Azerbaijan State Oil and Industry Academy, Master's Student, Baku, Azerbaijan
[*]Corresponding author. E-mail: ada_avia@yahoo.com
Received: 24 June 2026; Accepted: 9 October 2026; Published online: 9 November 2026
© The Author(s) 2026. This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).

Unlike traditional monitoring methods, this approach allows for more rapid data acquisition and remote monitoring of ongoing processes (Atzori et al., 2010; Gubbi et al., 2013). Integrating sensor technologies with IoT platforms significantly expands the functional capabilities of smart monitoring systems. Sensors measuring parameters such as temperature, humidity, pressure, vibration, and gas concentration provide real-time information regarding the physical status of objects (Li et al., 2015). Nevertheless, the deployment of such systems is accompanied by technical challenges, including data latency, power supply constraints, device interoperability, and cybersecurity risks. The objective of this paper is to analyze the design principles, functional architecture, and application potential of smart monitoring systems based on sensor-equipped IoT devices within a sociotechnical context.

Methods

The methodological foundation of this research is based on a systematic and comparative analysis of design principles for smart monitoring systems utilizing sensor-enabled IoT devices. The study employs analytical literature review, functional modeling, architectural classification, and synthesis methods. These methodologies facilitate a precise evaluation of the four-layered structural elements of IoT systems, data collection and transmission mechanisms, as well as the network protocols implemented within the monitoring process.

Results

Internet of Things (IoT) technology represents a key milestone in modern information and communication technologies, enabling physical objects, devices, and diverse sensor systems to establish mutual communication over the Internet. The primary purpose of IoT systems is the automated collection, processing, and presentation of data obtained from physical objects located in various environments to end-users. Owing to this technology, conventional monitoring methods are replaced by more efficient and operational mechanisms.

IoT systems typically feature a multi-layered architecture that ensures seamless interaction among different technological components. Consequently, the application of IoT technologies makes it possible to acquire large volumes of data concerning the state of various objects. Analyzing these data optimizes management processes and facilitates more rational decision-making.

Sensor technologies constitute one of the core components of IoT systems, ensuring the effective operation of monitoring networks. Sensors are specialized instruments designed to measure various physical, chemical, and biological parameters. These devices convert measured physical quantities into electrical signals and transmit them to a central control unit for processing. Modern sensors are distinguished by high precision, low power consumption, and long operational lifespans. Furthermore, their compact dimensions and wireless communication capabilities allow for versatile deployment in diverse environments.

Designing IoT-based smart monitoring systems encompasses a series of complex technical and software development stages, each playing a critical role in system efficiency. In the initial stage, the object or process to be monitored is defined, and the essential parameters requiring measurement are selected. For instance, in industrial plants, equipment temperature, mechanical vibration, and power consumption may be established as primary parameters. The subsequent phase involves selecting appropriate sensors and measuring instruments while considering technical specifications, measurement accuracy, and energy consumption. Determining optimal spatial positions for sensor placement is also executed during this phase.

Thereafter, the communication infrastructure for data transmission is established. Here, an adequate network technology is selected based on coverage area requirements and data transfer speed. For

example, LoRaWAN technology is considered more cost-effective for sensor networks distributed over expansive geographic areas. In the final phase, software systems are developed to execute data collection, storage, analysis, and visualization. Cloud computing and Big Data platforms are heavily utilized in modern monitoring systems for advanced data analytics (Gubbi et al., 2013).

Designing IoT-based smart monitoring systems requires organizing interconnected hardware and software components into a unified architecture (Miorandi et al., 2012). The system consists of four primary functional layers:

1. *Sensing / Perception Layer:* Houses sensor nodes that convert physical and chemical changes into electrical and digital signals.
2. *Network / Communication Layer:* Ensures secure data transmission to gateways, central servers, or cloud platforms.
3. *Data Processing and Analytics Layer:* Conducts filtering of incoming data, anomaly detection, and preliminary analytics.
4. *Application and User Layer:* Provides visual management dashboards and reporting interfaces via web and mobile platforms.

Sensors serve as the primary source of input data in IoT systems. According to their functional characteristics, they are classified into four main groups: physical sensors (temperature, pressure, vibration), chemical sensors (gas concentration), optical sensors (radiation intensity), and biological sensors. Key selection criteria during system design include measurement range, accuracy class, response time, and calibration intervals.

The selection of a communication protocol must be based on a comparative evaluation of transmission distance, energy budget, data transfer rate, and network density (Table 1).

Table 1
Comparison of communication technologies in ıot monitoring systems

Technology	Key Feature	Primary Application Field	Main Limitations to Consider
Wi-Fi	High data transfer speed	Indoor facilities, laboratories, localized monitoring	High energy consumption and limited coverage range
Bluetooth LE	Low power consumption	Short-range wearable and localized sensors	Restricted communication distance
ZigBee	Mesh sensor network organization	Smart buildings, industrial automation	Network configuration complexity
LoRaWAN	Wide area coverage and low energy demand	Agriculture, environmental monitoring	Low data transmission speed
NB-IoT	Utilizes cellular operator infrastructure	Long-distance telemetries	Dependency on mobile network operator coverage
5G	Ultra-high speed and low latency	Industrial automation and smart city solutions	High infrastructure and deployment costs

Sensor-based IoT systems find applications across multiple domains. In industry, monitoring vibration and temperature indicators enables early detection of equipment failures. In agriculture, implementing moisture control technologies facilitates the rational use of water resources (Arifzade, 2023). In urban infrastructure, IoT plays a pivotal role in optimizing traffic flow and energy distribution networks (Zanella et al., 2014).

Discussion

The efficiency of smart monitoring systems depends not solely on sensor measurement precision, but on the integration quality of all system components. Hybrid deployment of edge computing and cloud computing models in data processing mitigates central network load and reduces transmission latencies.

Information security represents one of the paramount challenges in IoT environments. Device identification, data encryption, and access control management are of critical importance (Roman et al., 2013; Sicari et al., 2015). Particularly in oil-and-gas and industrial facilities, cybersecurity analyses demonstrate that information security breaches can lead to severe industrial accidents (Quliyeva, 2025).

Conclusion

Smart monitoring systems constructed on sensor-enabled IoT devices play a critical role in the advancement of modern digital technologies. By enabling real-time data collection and analysis, these systems enhance the overall efficiency of operational management processes. The deployment of IoT technologies facilitates more effective resource utilization, timely risk identification, and improved decision-making mechanisms across various domains. In the future, the further evolution of artificial intelligence and Big Data technologies will continue to expand the operational capabilities of IoT-based monitoring systems.

References

Arifzade, N. (2023). Moisture control in agricultural facilities. *Qadim Diyar*, *5*(4), 155–158. https://doi.org/10.36719/2706-6185/22/155-158

Ashton, K. (2009, June 22). That ‘Internet of Things’ thing. *RFID Journal*. https://www.rfidjournal.com/that-internet-of-things-thing

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, *54*(15), 2787–2805. https://doi.org/10.1016/j.comnet.2010.05.010

Borgia, E. (2014). The Internet of Things vision: Key features, applications and open issues. *Computer Communications*, *54,* 1–31. https://doi.org/10.1016/j.comcom.2014.09.008

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, *29*(7), 1645–1660. https://doi.org/10.1016/j.future.2013.01.010

Li, S., Xu, L. D., & Zhao, S. (2015). The Internet of Things: A survey. *Information Systems Frontiers*, *17,* 243–259. https://doi.org/10.1007/s10796-014-9492-7

Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012). Internet of things: Vision, applications and research challenges. *Ad Hoc Networks*, *10*(7), 1497–1516. https://doi.org/10.1016/j.adhoc.2012.02.016

Quliyeva, T. (2025). Threats to the information security of oil and gas extraction companies. *Qadim Diyar*, *7*(2), 388–391. https://doi.org/10.36719/2706-6185/44/388-391

Roman, R., Zhou, J., & López, J. (2013). On the features and challenges of security and privacy in distributed Internet of Things. *Computer Networks*, *57*(10), 2266–2279. https://doi.org/10.1016/j.comnet.2012.12.018

Sadiqli, K. (2024). Fourth industrial revolution: Shaping the future of economic growth and innovation. *Qadim Diyar*, *6*(3), 224–233. https://doi.org/10.36719/2706-6185/33/224-233

Sicari, S., Rizzardi, A., Grieco, L. A., & Coen-Porisini, A. (2015). Security, privacy and trust in Internet of Things: The road ahead. *Computer Networks, 76,* 146–164. https://doi.org/10.1016/j.comnet.2014.11.008

Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of Things for smart cities. *IEEE Internet of Things Journal*, *1*(1), 22–32. https://doi.org/10.1109/JIOT.2014.2306328

Journal of Technology Studies
November 2026, Volume: 3, Issue: 4, pp. 10−14
DOI: https://doi.org/10.36719/3104-4735/6/10-14

Science and Technology Enlightenment in "Fuyuzat" Magazıne: Sociolinguistic and Social-philosophical Perspectıves on Promotıng Ideas of Social Progress Through the Press in the Late 19th and Early 20th Centurıes

Vusala Asadova

Abstract. *This study analyzes the promotion of scientific and technical enlightenment ideas in Fuyuzat magazine (1906–1907)—one of the most prominent press examples of Azerbaijani social-philosophical and literary thought in the early 20th century—and the role of these ideas in the digital-sociological and cultural transformation of society using sociolinguistic and historical-comparative methods. The primary goal of the study is to illuminate the role of the Fuyuzat movement, edited by Ali bey Huseynzade, not merely as an environment for national cognition and romantic poetry, but also as an enlightenment platform integrating European scientific and technical achievements, engineering thought, industrial innovations, and natural sciences into the Eastern world. The article systemizes the technological and scientific infrastructure components of the idea of "modernization" advocated in the magazine's pages and substantiates the theoretical-conceptual continuity between the press language of that era and the priorities of the modern digital information society.*

Keywords: *Fuyuzat magazine, Ali bey Huseynzade, scientific enlightenment, technology promotion, social progress, sociolinguistics, digital transformation*

Introduction

The late 19th and early 20th centuries are characterized as a period of fundamental transformations in the social, socioculture, and scientific-philosophical thought of Azerbaijan. The rapid development of the oil industry and the transformation of Baku into a global capitalist and industrial center presented new scientific and technological challenges to the national intelligentsia. During this historical stage, the national press served not only as a bearer of socio-political news, but also as a primary enlightenment tool aimed at rescuing society from illiteracy, superstition, and industrial backwardness (Sadiqli, 2024). Published between 1906 and 1907 with the financial support of Haji Zeynalabdin Taghiyev and under the chief editorship of the prominent thinker Ali bey Huseynzade, *Fuyuzat* magazine played the role of an ideological and theoretical vanguard in this process. In traditional historiography, *Fuyuzat* magazine is mostly evaluated as the founder of a romantic literary school, aesthetics, and the tripartite formula of "Turkicize, Islamize, Europeanize (Modernize)." However, when the philosophical architecture of the magazine is closely examined, it becomes clear that what Ali bey Huseynzade meant by "Europeanize" was primarily the adoption of Western scientific and technical achievements, industrial innovations, and rationality (Gahramanova, 2025). The interpretation of technological innovations of the era in the press medium formed the technological foundation of national intellectual rebirth.

Azerbaijan State Pedagogical University, PhD Philology, Baku, Azerbaijan
E-mail: vasadova1984@gmail.com
Received: 2 Jule 2026; Accepted: 1 October 2026; Published online: 9 November 2026
© The Author(s) 2026. This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).

In the modern era of digitalization and artificial intelligence, the mutual relationship between the nature of information technologies and the structure of language and society is among the priority research areas (Crystal, 2011; Gahramanova, 2026a). In this regard, studying the mechanisms of promoting scientific and technical knowledge in *Fuyuzat* magazine creates a historical-theoretical bridge between past enlightenment models and modern digital pedagogical tools and the information society (Abdelkader et al., 2026). The purpose of this study is to filter the manifestations of scientific enlightenment and technological progress in *Fuyuzat* magazine through modern sociolinguistic analysis.

Methods

This research employs an interdisciplinary and comprehensive analytical methodology to examine press texts published in the late 19th and early 20th centuries. The methodological framework of the study consists of the following scientific approaches:

1. Historical-Comparative and Conceptual Analysis: Scientific, publicistic, and philosophical essays published across 32 issues of *Fuyuzat* magazine were comparatively analyzed within the context of modern digital technology and industrial revolution theories.

2. Sociolinguistic and Textual Discourse Analysis: The frequency of scientific-technical terms (physics, medicine, astronomical instruments, engineering terms) in the magazine's language and their adaptation from Ottoman/Arabic-Persian terminology into the native language framework and European terminological system were evaluated from a sociolinguistic perspective (Androutsopoulos, 2014).

3. Analytical Classification: Enlightening materials in the magazine were grouped according to content parameters (natural sciences, industrial-technical progress, medicine/hygiene, and educational technologies) and systemized into table format.

The research relies on original text copies of *Fuyuzat* magazine and their digital transcriptions as empirical data.

Results

The interdisciplinary analytical research demonstrates that *Fuyuzat* magazine was an essential media platform that re-formatted not only literary-aesthetic thought but also the scientific-technological worldview of society. Scientific enlightenment in the magazine was realized along three primary vectors:

Technological Content of the Concept of "Europeanization". The concept of Europeanization advanced by Ali bey Huseynzade in *Fuyuzat* was not a blind imitation of Western lifestyle, but rather the acquisition of Western technical sciences, engineering thinking, and experimental methodology. Articles emphasized that safeguarding national independence and economic sustainability was impossible without adopting Western technology (Gahramanova, 2026b). In this respect, *Fuyuzat* presented industrial technologies as a defense mechanism for national existence.

Formalization of scientific-technical terminology in language. Just as the influx of foreign technology terms creates morphological hybridization in the digital era (Ceviz & Doğan, 2021), integrating scientific terms of European origin into the Azerbaijani language was a major linguistic challenge in the early 20th century. *Fuyuzat* magazine strove to form the initial scientific-technical lexical database by utilizing Arabic and Persian linguistic resources alongside European terminology.

Enlightenment Domain	Primary Thematic Focus in Magazine	Promoted Technological/Scientific Concept	Impact on Social Progress
Industry & Engineering	Oil extraction, machinery, railways	Steam engines, electrical machinery	Spurred the training of national industrial specialists
Natural Sciences & Physics	Structure of the universe, physical laws	Experimental physics & astronomical observations	Eradication of superstition and religious dogmatism
Medicine & Hygiene	Combating epidemics, human anatomy	Microbiology, modern medical technology	Physical and health education of the population
Educational Technology	New method schools (Usul-i Jadid)	Application of visual aids and spatial tools	Massification of literacy and education

Source. Compiled by the author.

Discussion

The historical-theoretical analysis shows that *Fuyuzat* magazine, published in the early 20th century, was not merely a literary-artistic organ, but also played a major intellectual role in modernizing society, adopting scientific-technical innovations, and forming national consciousness. Synthesis of Western technical progress with Eastern moral values was a main topic of discussion among thinkers of that era.

A key aspect during discussion is that science and technology concepts promoted through the press were evaluated as the sole way out of backwardness for society. The interplay between journalism and enlightenment shows that forward-thinking intellectuals tried to maximize the power of the press to educate society. In this regard, *Fuyuzat* laid the foundation for a new stage in press history—scientific-technical and philosophical publicism.

Another important aspect is language and terminology in transferring technological innovations to society. Authors of the magazine, led by Ali bey Huseynzade, paid special attention to formulating new scientific terms in the native language and delivering technical knowledge in simple language. This approach stimulated scientific thinking in the native language.

Analysis of historical press demonstrates that newspapers and magazines in the early 20th century were not just news outlets, but powerful intellectual tools managing socio-cultural transformation. The legacy of *Fuyuzat* proves that presenting science and technology to society was always accompanied by deep philosophical and ideological context.

In modern times, studying this historical legacy requires new methodological approaches. Analyzing historical press samples and connecting them with modern communication systems is widely discussed in scientific literature within digital humanities. Forms of traditional enlightenment ideas in modern digital society show that past scientific-technical views maintain their relevance today.

Research also shows that the development dynamics of national press and social thought history are closely linked. Publications like *Fuyuzat* played an important role in shaping national self-awareness

(Gahramanova, 2025). At the same time, the role of traditional press and its influence mechanisms in the digital era serve as subjects of new scientific research (Gahramanova, 2026a). Conceptual metaphors in political and social discourse explain the process of shaping public opinion through the press (Gahramanova, 2026b). The role of the Fourth Industrial Revolution in shaping innovation and economic growth demonstrates that the technological progress line from past to present is continuous (Sadiqli, 2024).

Analyzing scientific-technological enlightenment in *Fuyuzat* magazine indicates that social progress depends directly on technological literacy alongside political and literary ideas. As in modern sociolinguistic and technological theories (Herring, 2013; Tagliamonte & Denis, 2008), media language and technological tools reformat society's mindset. While *Fuyuzat* realized this transformation through print press in the early 20th century, digital media and AI tools fulfill this mission today.

Ali bey Huseynzade and his colleagues (Muhammad Hadi, Huseyn Javid, Ahmad Kamal, etc.) well understood that a society isolated from scientific-technical knowledge could not withstand global competition. This theoretical approach aligns with modern ideas of digitalizing and humanizing teacher-student relationships in higher education (Gahramanova, 2026). The scientific rationality promoted by *Fuyuzat* constituted the intellectual foundation of national ideology.

Similar to mechanisms of adopting digital terminology in German and English (Androutsopoulos, 2007; Seargeant & Tagg, 2014), *Fuyuzat* attempted to present neologisms of Western science through the syntactic and morphological filter of the native language. Today's imperative to develop Azerbaijani language corpora and NLP tools (Gahramanova, 2026a) represents the moral and technological continuation of the scientific-linguistic traditions established by *Fuyuzat* enlightenments.

Conclusion

This comprehensive sociolinguistic and historical-theoretical study allows for summarizing the following scientific conclusions:

1. *Fuyuzat* magazine acted in Azerbaijani press history not only as a romantic-literary publication, but also as a promoter of industrial revolution, scientific rationality, and technological innovations.
2. At the core of Ali bey Huseynzade's concept of "Europeanization" lay the goal of mastering Western scientific-technical achievements and forming a national industrial infrastructure.
3. The scientific enlightenment traditions of *Fuyuzat* preserve their theoretical value in the age of digital transformation and artificial intelligence, offering vital historical experience for developing the native language and cognition in digital environments.

References

Abdelkader, M., Zakariyya, S. S. A., & Ahmad, M. (2026). Gamma as a digital pedagogical tool enhancing student engagement, autonomy, and motivation in blended language learning contexts. *Elmi Ish*, *20*(6), 137–160.

Androutsopoulos, J. (2007). Language choice and code-switching in German-based online environments. *Pragmatics and Beyond New Series*, *157*, 340–361.

Androutsopoulos, J. (2014). Computer-mediated communication and linguistic landscapes. *International Journal of Multilingualism*, *11*(1), 74–90. https://doi.org/10.1080/14790718.2013.811581

Ceviz, M., & Doğan, A. (2021). Digital transformation of Turkish and language deviations in the social media age. *Belleten - Annual of Turkish Language Research*, *69*(2), 145–168.

Crystal, D. (2011). *Internet Linguistics: A Student Guide*. Routledge.

Gahramanova, F. (2026). Humanist approach in teacher-student relationships. *Qadim Diyar*, *8*(8), 33–38.

Herring, S. C. (2013). Discourse in Web 2.0: Familiar boundaries, new records. *Georgetown University Round Table on Languages and Linguistics*, 81–102.

Gahramanova, Y. (2025). Uzeyir Hajibeyli as a defender of our national language. *Elmi Ish (Proceedings of the XXV International Scientific Conference)*, 45–48.

Gahramanova, Y. (2026a). Impact of digitalization on language: AI's level of comprehension of semantic integrity and syntactic adequacy in language. *Qadim Diyar*, *8*(8), 115–121.

Gahramanova, Y. (2026b). Conceptual metaphors in political discourse: Mechanisms of shaping thinking and public opinion in digital media speech. *Qadim Diyar*, *8*(8).

Sadiqli, K. (2024). Fourth industrial revolution: Shaping the future of economic growth and innovation. *Qadim Diyar*, *6*(3), 224–233. https://doi.org/10.36719/2706-6185/33/224-233

Tagliamonte, S. A., & Denis, D. (2008). Linguistic variables in the new media. *Journal of Sociolinguistics*, *12*(1), 3–31. https://doi.org/10.1111/j.1467-9841.2008.00350.x

Journal of Technology Studies
November 2026, Volume: 3, Issue: 4, pp. 15−21
DOI: https://doi.org/10.36719/3104-4735/6/15-21

Modern Water Purification Technologies: Integrated Treatment Processes and Sustainable Applications

Hacı Beytullah Mutlu

Abstract. *Water purification is essential for protecting public health, supporting economic activity, and reducing pressure on freshwater resources. This article reviews conventional and advanced technologies used to improve the quality of surface water, groundwater, and saline sources. It outlines the roles of source protection, coagulation and flocculation, sedimentation, granular and membrane filtration, adsorption, and disinfection within a multi-barrier treatment approach. Particular attention is given to membrane processes, including microfiltration, ultrafiltration, nanofiltration, reverse osmosis, forward osmosis, and electrodialysis, with emphasis on their separation mechanisms, operational requirements, and limitations. The study uses a narrative and comparative review of technical literature, standards, and recent research, including work published in Azerbaijani scientific journals on Caspian Sea desalination and water-resource protection. The comparison shows that no single method is suitable for every source: treatment trains should be selected according to raw-water quality, target contaminants, required water quality, energy demand, maintenance capacity, and residual management. The article concludes that combining appropriate treatment stages with routine monitoring and effective source-water governance offers a practical basis for reliable and sustainable water purification.*

Keywords: *water purification, drinking-water quality, coagulation and flocculation, filtration, membrane technologies, reverse osmosis, nanofiltration, disinfection*

Introduction

Access to safe water depends not only on the availability of water resources but also on the ability to protect, treat, distribute, and monitor them. Surface water and groundwater may contain microbial hazards, suspended matter, dissolved salts, natural organic compounds, and contaminants introduced by agriculture, industry, and urban activity. The World Health Organization (WHO, 2026) therefore frames drinking-water safety as a preventive, risk-based process that extends from the catchment to the consumer and combines health-based targets, water safety planning, and independent surveillance.

Treatment technologies are most effective when they form part of an integrated system rather than being selected as isolated devices. Source protection, pretreatment, clarification, filtration, disinfection, and routine monitoring each address different classes of hazards. For Azerbaijan, the protection and sustainable management of water resources are also important institutional and environmental priorities, particularly where pollution pressures and transboundary water issues are involved (Allahverdiyev, 2025).

Istanbul, Türkiye
E-mail: utopyamutlu@gmail.com
Received: 2 Jule 2026; Accepted: 6 October 2026; Published online: 9 November 2026
© The Author(s) 2026. This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).

This article reviews the principal processes used in modern water purification, compares conventional and membrane-based technologies, and considers the conditions under which household and small-scale systems may be appropriate. The aim is to provide a concise technical overview that connects treatment performance with source-water quality, operational requirements, and long-term sustainability.

Methods

The article is based on a narrative review and comparative analysis of technical books, drinking-water guidance, standard analytical methods, and recent research relevant to water treatment. Technologies are compared according to their principal removal mechanisms, target contaminants, operating requirements, maintenance needs, and potential environmental trade-offs. Particular attention is paid to filtration and membrane processes because they play a central role in the treatment of turbid, saline, and dissolved-contaminant-bearing waters. The discussion also draws on recent Azerbaijani research addressing nanofiltration in hybrid Caspian Sea desalination systems and the legal protection of national water resources (Ahmadova & Rustamli, 2026; Allahverdiyev, 2025). This is a narrative technical review; it does not report new laboratory experiments or claim a systematic database search. In practice, raw-water and treated-water samples should be collected and analysed using validated procedures, such as those described in Standard Methods (American Public Health Association et al., 2017).

1. Water Sources and Common Contaminants

The principal sources used for water supply are surface waters, including rivers, lakes, and reservoirs, and groundwater stored in aquifers. Their quality varies with geology, land use, climate, and human activity. Surface waters are generally more exposed to runoff, erosion, wastewater discharges, and seasonal changes. They may contain suspended sediments, algae, natural organic matter, nutrients, pathogenic bacteria, viruses, and protozoa. Agricultural and urban runoff can also introduce pesticides, nitrates, hydrocarbons, and other chemical substances (WHO, 2026).

Groundwater is often less turbid because soil and geological layers provide a degree of natural filtration. Nevertheless, groundwater may contain naturally occurring dissolved substances, including arsenic, fluoride, iron, manganese, and salts, depending on local geology. Nitrate contamination may arise from fertilisers, animal waste, or poorly managed sanitation systems. Consequently, the choice of treatment should be based on a site-specific analysis rather than on the assumption that surface water is always more contaminated or that groundwater is inherently safe. Protecting water sources and strengthening pollution-prevention measures are necessary complements to treatment at the plant or household level (Allahverdiyev, 2025; WHO, 2026).

2. Conventional Water Treatment Processes

2.1. Pretreatment, Coagulation, Flocculation, and Sedimentation

Pretreatment removes coarse debris and prepares raw water for subsequent processes. Bar screens, strainers, and grit-removal units protect pumps and other equipment from leaves, branches, sand, and similar material. Where necessary, pH adjustment and chemical conditioning are used to create conditions suitable for clarification.

Coagulation involves adding a coagulant, commonly an aluminium- or iron-based salt, to destabilise fine suspended and colloidal particles. During flocculation, controlled mixing encourages these particles to combine into larger aggregates, or flocs, that can be removed by sedimentation or flotation. The required coagulant dose and operating pH depend on the raw-water characteristics and should be established through appropriate testing, such as jar tests. Poor control may increase

chemical consumption, produce excessive sludge, or reduce downstream filtration performance (Bratby, 2016; Crittenden et al., 2012).

Sedimentation allows heavier flocs to settle under gravity before filtration. It reduces the solids load on filters and can improve the stability of the overall treatment train. Sludge generated during clarification must be collected and managed safely; returning untreated sludge or wash water to the source may reintroduce contaminants.

2.2. Filtration and Adsorption

Filtration removes particles that remain after clarification and, depending on the filter medium and operating conditions, can reduce a portion of the microbial load. Rapid gravity or pressure sand filters use granular media and are commonly applied after coagulation and sedimentation. Their performance depends on media characteristics, filtration rate, bed depth, pretreatment quality, and filter operation. Accumulated solids increase head loss, so periodic backwashing is required (Crittenden et al., 2012).

Slow sand filters operate at lower filtration rates and rely on both physical retention and biological activity within the upper layer of the filter bed. They can be useful for small or decentralised supplies where land and operating time are available. However, their performance depends on appropriate maturation, careful operation, and suitable raw-water turbidity. Ceramic household filters are another point-of-use option; field performance varies with design, manufacturing quality, handling, and maintenance, so products should be selected on the basis of independent testing rather than general claims (Lantagne, 2001).

Activated carbon is used primarily to adsorb taste and odour-causing compounds and certain dissolved organic substances. It may be installed as granular activated carbon in treatment plants or as a replaceable cartridge in household devices. Activated carbon is not a universal barrier: it does not reliably remove dissolved salts, and its performance depends on the contaminant, contact time, carbon condition, and replacement schedule. It should therefore be selected for a defined treatment objective and combined with other processes when necessary (Crittenden et al., 2012).

2.3. Disinfection

Disinfection is intended to inactivate pathogenic microorganisms remaining after clarification and filtration. Chlorine-based compounds are widely used because they are effective against many bacteria and viruses and can maintain a disinfectant residual in the distribution system. Their application requires control of dose, contact time, pH, and water quality; reaction with natural organic matter may form disinfection by-products. Ultraviolet (UV) treatment inactivates microorganisms without adding a chemical residual, but its performance depends on adequate UV transmittance, lamp condition, and the absence of excessive turbidity. Disinfection should therefore be treated as one barrier within a multi-stage process, not as a substitute for removing particles and chemical contaminants (WHO, 2026).

3. Advanced and Membrane-Based Technologies

3.1. Microfiltration and Ultrafiltration

Microfiltration and ultrafiltration use pressure-driven membranes to retain suspended particles and microorganisms according to membrane characteristics and operating conditions. They can provide a compact alternative or supplement to granular filtration and are often used as pretreatment for more selective membrane processes. Their limitations include membrane fouling, pressure loss, cleaning requirements, and the need for appropriate management of backwash streams and cleaning wastes.

Membrane integrity and treated-water quality should be monitored throughout operation (Crittenden et al., 2012; WHO, 2026).

3.2. Nanofiltration and Reverse Osmosis

Nanofiltration (NF) is particularly useful for reducing hardness and retaining many multivalent ions and selected organic compounds. Reverse osmosis (RO) applies greater pressure across a semipermeable membrane and is used to reduce dissolved salts and a broad range of dissolved contaminants. Both processes can produce high-quality permeate, but their efficiency depends on feed-water composition, membrane selection, pressure, recovery ratio, and pretreatment. Scaling and fouling can reduce flux and increase energy use; the concentrate stream also requires environmentally appropriate management (Crittenden et al., 2012).

The use of nanofiltration as a pretreatment step is relevant to hybrid desalination systems. This study examines the use of nanofiltration within hybrid systems for the treatment of Caspian Sea water and discusses its potential to prevent the formation of sulfate deposits (scaling) on reverse osmosis membranes and thermal distillation surfaces in subsequent stages (Ahmadova & Rustamli, 2026). This local study provides a useful example of how membrane selection and pretreatment can be adapted to the chemical composition of a specific water source. Its findings should be interpreted in the context of the feed-water conditions and system configuration considered by the authors.

3.3. Forward Osmosis and Electrodialysis

Forward osmosis uses an osmotic pressure difference between feed water and a concentrated draw solution to move water through a semipermeable membrane. It may be considered for selected concentration or desalination applications, although the draw solution must subsequently be regenerated and this can add energy demand and process complexity. Electrodialysis uses an electric field and ion-selective membranes to move dissolved ions from one stream to another. It is generally considered for brackish or moderately saline water; its suitability depends on salinity, water recovery, electricity cost, and scaling or fouling risks. These methods should be evaluated against RO and other options using site-specific technical and economic data.

Table 1
Comparative overview of selected water purification technologies

Technology	Main treatment function	Advantages	Main limitations / controls
Coagulation and flocculation	Destabilises colloids and aggregates fine particles for later removal.	Improves clarification and reduces the solids load on filters.	Coagulant dose and pH need optimisation; sludge must be managed.
Sand filtration	Retains suspended particles and reduces turbidity after clarification.	Established, relatively simple treatment stage.	Requires suitable pretreatment, head-loss monitoring, and backwashing or surface cleaning.
Activated carbon	Adsorbs selected dissolved organic compounds and taste- or odour-causing substances.	Can improve aesthetic quality and reduce some organic contaminants.	Does not remove dissolved salts reliably; media must be replaced or regenerated.

Technology	Main treatment function	Advantages	Main limitations / controls
Microfiltration / ultrafiltration	Membrane barrier for particles and many microorganisms.	Compact process; can serve as a pretreatment or clarification step.	Membrane fouling, integrity monitoring, cleaning, and residual management are required.
Nanofiltration / reverse osmosis	Removes selected dissolved ions and, in RO, a broad range of dissolved salts.	Suitable for softening, demineralisation, and desalination.	Energy demand, scaling, fouling, pretreatment, and concentrate disposal must be considered.
Chlorination / UV disinfection	Inactivates susceptible microorganisms.	Chlorine can provide a residual; UV avoids chemical addition.	Chlorine may form by-products; UV needs clear water and reliable power; neither removes dissolved chemicals.

Source. Compiled by the author based on Bratby (2016), Crittenden et al. (2012), and WHO (2026).

Membrane technologıes and emergıng contamınants. Recent research has increasingly focused on improving membrane-based water purification technologies to address the limitations of conventional treatment methods. Microfiltration, ultrafiltration, nanofiltration, and reverse osmosis differ in their separation mechanisms and effectiveness in removing suspended particles, microorganisms, dissolved salts, and emerging chemical contaminants. The performance of these technologies depends on membrane composition, pore structure, surface properties, and the physicochemical characteristics of the source water. Studies have demonstrated that membrane modification and the incorporation of nanomaterials can improve filtration performance and contribute to the removal of a broader range of pollutants (Aziz et al., 2024; Cevallos-Mendoza et al., 2022). Furthermore, recent developments in membrane science have explored integrated separation and degradation approaches for emerging pollutants that may not be adequately eliminated through conventional treatment processes (Zhao et al., 2024). However, membrane fouling, energy consumption, and maintenance requirements remain important factors when selecting an appropriate treatment system.

Mıcrobıologıcal safety and ıntegrated water treatment. An important aspect of water purification is the reliable removal or inactivation of microbiological contaminants. Recent systematic reviews indicate that the effectiveness of physical treatment processes, including granular filtration, slow sand filtration, membrane separation, and clarification, varies depending on the type of microorganism, source-water quality, and operational conditions (Burke et al., 2025). At the household level, ceramic filters, membrane-based systems, ultraviolet irradiation, thermal treatment, and chemical disinfection represent important approaches to improving drinking-water safety. Nevertheless, their effectiveness depends not only on the technical characteristics of the devices but also on proper operation, regular maintenance, and consistent use (Rao et al., 2025). In this regard, the integration of several treatment stages provides a more comprehensive approach to water purification. Combining source-water protection, pre-treatment, filtration, and disinfection is consistent with established water-treatment principles and international drinking-water quality recommendations (Bratby, 2016; Crittenden et al., 2012; World Health Organization [WHO], 2017).

4. Household and Point-of-Use Treatment

Household and field-based systems are designed for situations where a centralised supply is unavailable, unreliable, or requires an additional treatment barrier. Common options include ceramic and other mechanical filters, chlorine-based disinfectants, UV devices, and small reverse-osmosis

units. The appropriate option depends on the contaminants present: disinfection can reduce microbial risk but does not remove dissolved metals or salts, while membrane systems may reduce dissolved contaminants but require more careful maintenance and management of reject water. Household devices should be used according to validated performance claims and manufacturer instructions, and treated water must be stored in clean, covered containers to avoid recontamination (Lantagne, 2001; WHO, 2026).

No single household technology addresses every possible hazard. For example, a particle filter may improve clarity without removing dissolved chemicals; chlorine may inactivate many pathogens but is less effective against some chlorine-resistant protozoa; and UV treatment is less reliable when water is highly turbid. Where chemical contamination is suspected, a microbial disinfection method alone is insufficient. Source-water testing and selection of a treatment method certified for the contaminant of concern are therefore essential.

Discussion

The review indicates that treatment selection should begin with an assessment of raw-water quality and the intended use of the treated water. A conventional treatment train combining coagulation, flocculation, sedimentation, filtration, and disinfection may be appropriate for many surface-water supplies. Where dissolved salts, hardness, or selected micropollutants are the main concern, membrane technologies may be required. In all cases, the additional benefits of advanced treatment should be weighed against energy consumption, chemical use, maintenance capacity, concentrate or sludge disposal, and the ability to monitor performance over time.

The Azerbaijani studies considered here highlight two complementary dimensions of water security. Ahmadova and Rustamli (2026) address a technical challenge in Caspian Sea desalination by examining nanofiltration as part of a hybrid treatment train. Allahverdiyev (2025), by contrast, focuses on the legal and institutional protection of water resources and the need for effective implementation, monitoring, and coordination. Taken together, these works reinforce the point that sustainable water purification depends on both suitable engineering and sound resource governance.

Performance verification should be part of routine operation. Monitoring may include turbidity, pH, conductivity, disinfectant residual, membrane pressure and flux, and relevant microbiological or chemical parameters. The indicators selected must match the source-water risks and treatment objectives. Sampling and laboratory analysis should follow recognised procedures, and results should be interpreted against the applicable national requirements and current international guidance (American Public Health Association et al., 2017; WHO, 2026).

Conclusion

Water purification is most reliable when it is designed as a multi-barrier process that combines source protection, appropriate pretreatment, clarification, filtration, and disinfection. Conventional processes remain important for removing suspended solids and controlling microbial hazards, while membrane technologies extend treatment capability to dissolved salts, hardness, and selected chemical contaminants. Nanofiltration can also serve as a useful pretreatment in hybrid desalination systems, provided that its performance is evaluated for the specific feed-water composition.

The selection of a treatment system should be based on verified water-quality data, the intended use of the treated water, operational capacity, energy requirements, maintenance needs, and safe management of treatment residuals. Household devices can provide an additional barrier in appropriate settings, but they are not interchangeable and should not be assumed to remove all contaminants. Ultimately, reliable water purification requires regular monitoring, transparent management, and effective protection of water sources alongside technological improvement.

References

Ahmadova, J., & Rustamli, N. (2026). Research of some technological aspects of the nanofiltration method in hybrid desalination systems of Caspian Sea water. *Scientific Work International Scientific Journal, 20*(1), 185–189. https://doi.org/10.36719/2663-4619/125/185-189

Allahverdiyev, A. (2025). Legal protection of Azerbaijan's water resources: Problems and prospects. *Ancient Land International Scientific Journal, 7*(12), 139–143. https://doi.org/10.36719/2706-6185/54/139-143

American Public Health Association, American Water Works Association, & Water Environment Federation. (2017). *Standard methods for the examination of water and wastewater* (23rd ed.). APHA Press.

Aziz, S., Mazhar, A. R., Ubaid, A., Shah, S. M. H., Riaz, Y., Talha, T., & Jung, D.-W. (2024). *A comprehensive review of membrane-based water filtration techniques.* Applied Water Science, 14, Article 169. https://doi.org/10.1007/s13201-024-02226-y

Bratby, J. (2016). *Coagulation and flocculation in water and wastewater treatment* (3rd ed.). IWA Publishing.

Crittenden, J. C., Trussell, R. R., Hand, D. W., Howe, K. J., & Tchobanoglous, G. (2012). *MWH's water treatment: Principles and design* (3rd ed.). John Wiley & Sons.

Kumar, M., Shekhar, S., Kumar, R., Kumar, P., Govarthanan, M., & Chaminda, T. (2023). Drinking water treatment and associated toxic byproducts: Concurrence and urgence. *Environmental Pollution, 320,* Article 121009. https://doi.org/10.1016/j.envpol.2023.121009

Lantagne, D. S. (2001). *Investigation of the Potters for Peace ceramic water filter project in Nicaragua: Executive summary report.* Massachusetts Institute of Technology, Department of Civil and Environmental Engineering.

MacKeown, H., Magi, E., Di Carro, M., & Benedetti, B. (2024). Removal of perfluoroalkyl and polyfluoroalkyl substances from tap water by means of point-of-use treatment: A review. *Science of the Total Environment, 954,* Article 176764. https://doi.org/10.1016/j.scitotenv.2024.176764

Taher, M. N., Al-Mutwalli, S. A., Barisci, S., Koseoglu-Imer, D. Y., Dumée, L. F., & Shirazi, M. M. A. (2024). Progress on remediation of per- and polyfluoroalkyl substances (PFAS) from water and wastewater using membrane technologies: A review. *Journal of Water Process Engineering, 59,* Article 104858. https://doi.org/10.1016/j.jwpe.2024.104858

Tushar, M. M. R., Pushan, Z. A., Aich, N., & Rowles, L. S. (2024). Balancing sustainability goals and treatment efficacy for PFAS removal from water. *npj Clean Water, 7*, Article 130. https://doi.org/10.1038/s41545-024-00427-1

World Health Organization. (2026). *Guidelines for drinking-water quality: Fourth edition incorporating the first, second, and third addenda.* https://www.who.int/publications/i/item/9789240121225

Journal of Technology Studies
November 2026, Volume: 3, Issue: 4, pp. 22–29
DOI: https://doi.org/10.36719/3104-4735/6/22-29

Application of New Technologies to Improve the Metrological Characteristics of Medical Devices

Khayal Abdullayev[1*], and Elshad Mammadli[2]

Abstract. *In the modern healthcare system, the accuracy and reliability of medical devices are considered key factors determining the effectiveness of diagnostic and treatment processes. The metrological characteristics of medical measurement systems are essential indicators that ensure the functional quality of these devices and the accuracy of clinical results. Metrological assurance encompasses the organization of measurement processes based on scientific principles, the maintenance of measurement accuracy, and the assurance of result reliability. The measurement accuracy, range, sensitivity, stability, and repeatability of results are of particular importance in the clinical application of medical devices. This article examines the application of modern technologies, including sensor systems, artificial intelligence algorithms, IoT-based monitoring solutions, and digital calibration methods, to improve the metrological performance of medical devices. It also considers the role of calibration in comparing measurement results with reference measurement standards and identifying potential measurement errors. The findings indicate that the use of these technologies can improve the measurement accuracy of medical devices, minimize errors, and enable real-time monitoring. Such approaches can enhance the effectiveness of metrological assurance and positively contribute to the reliability of diagnostic decisions and the overall quality of healthcare services.*

Keywords: *medical devices, metrological characteristics, calibration, sensor technologies, artificial intelligence, IoT systems*

Introduction

Metrological assurance is a comprehensive system of activities designed to organize measurement processes in accordance with scientific principles and to maintain the accuracy of the results obtained. The primary objective of metrological assurance for medical devices is to ensure the reliability of measurement results used in diagnosis and treatment. The accuracy and stability of medical measurement systems directly affect the overall quality of healthcare services. Therefore, the scientific study and improvement of the metrological characteristics of medical devices play an important role in the development of modern medical technologies (Morris & Langari, 2016). The metrological characteristics of medical devices comprise a set of parameters that describe the technical and functional performance of a measurement system. These parameters include measurement accuracy, measuring range, sensitivity, stability, and repeatability. Maintaining these indicators at an optimal level helps ensure the reliability of medical devices in clinical use. Since a large proportion of medical equipment used in modern healthcare is based on complex measurement and data-processing systems, the accuracy of its metrological characteristics is particularly important. One of the key stages in the metrological assurance of medical devices is calibration.

[1]Azerbaijan State Oil and Industry University, Baku, Azerbaijan
[2]Azerbaijan State Oil and Industry University, Master's Student, Baku, Azerbaijan
[*]Corresponding author. E-mail: xeyal.abdullayev96@gmail.com
Received: 24 May 2026; Accepted: 19 October 2026; Published online: 9 November 2026
© The Author(s) 2026. This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).

Calibration is performed by comparing the results produced by a measuring instrument with those of reference measurement standards, thereby identifying the instrument's measurement errors. When carried out regularly, this process helps ensure the correct and stable operation of medical devices and substantially improves the reliability of measurement results (Bostani et al., 2025; Chen et al., 2024).

Methods

This study used systematic analysis and comparative research methods to identify the role of modern technologies in improving the metrological characteristics of medical devices. Relevant scientific literature and existing technological approaches were reviewed to identify the principal metrological indicators of medical measurement systems. Sensor systems, artificial intelligence algorithms, Internet of Things (IoT)-based monitoring solutions, and digital calibration methods were compared in terms of their functional capabilities. The comparison focused on measurement accuracy, sensitivity, stability, repeatability, and the reduction of measurement errors. The effect of calibration on the reliability of measurement results and the operational quality of devices was also analyzed. Based on a synthesis of the information obtained, the potential applications of modern technologies for improving the metrological assurance of medical devices were evaluated.

Results

Metrological characteristics are key indicators for assessing the measurement quality and reliability of medical devices. Some of the main quality indicators of measuring instruments are presented in Table 1.

Table 1
Quality Indicators of measuring instruments

Quality indicators	Description and significance
Accuracy	Indicates how close a measurement result is to the true value and supports the correctness of clinical decisions.
Repeatability	Indicates the closeness of measurement results obtained under the same conditions and helps identify whether systematic-error correction may be needed.
Sensitivity	Describes the device's ability to detect small changes and makes it possible to identify sudden changes in a patient's condition.
Stability	Describes the long-term stability of device performance and its consistency over time, supporting metrological reliability.

Source. Prepared by the authors.

At present, the metrological assurance of medical devices is no longer limited to calibration and technical inspection. The rapid development of information technologies has created broad opportunities for automating and digitizing metrological processes. This approach enables more efficient management of medical device operation and real-time monitoring of their technical condition (Bohr & Memarzadeh, 2020).

The development of sensor technologies has played an important role in expanding the functional capabilities of medical devices and improving their metrological characteristics. Modern sensors can measure physiological and biochemical changes in the human body with high accuracy and are therefore widely used in diagnostic and monitoring systems.

Biosensors are among the key components of medical measurement systems. They analyze chemical reactions and biological processes in the body to measure various parameters. For example, glucose sensors enable continuous blood glucose monitoring in people with diabetes. Electrochemical sensors are also widely used to assess cardiac activity and determine blood oxygen levels.

The application of sensor technologies in medical devices offers several advantages. First, these technologies help increase measurement accuracy and minimize errors. In addition, sensor systems provide real-time data acquisition, enabling medical decisions to be made more promptly.

The development of sensor technologies has also made it possible to miniaturize medical devices. Modern portable medical equipment can be used in patients' everyday lives and allows their health status to be monitored continuously. This is particularly important for the management of chronic diseases (Morris & Langari, 2016).

Advances in artificial intelligence have opened up new opportunities for improving medical measurement systems. Artificial intelligence algorithms can rapidly process large volumes of data obtained from medical devices, thereby contributing to increased measurement accuracy.

Machine-learning methods can analyze sensor data and detect anomalies that arise during the measurement process. These algorithms can identify systematic errors and support their correction, thereby substantially improving the metrological performance of medical devices. Artificial intelligence technologies are also used to predict the technical condition of medical devices (Rabus et al., 2025). This approach makes it possible to identify potential malfunctions in advance and carry out preventive maintenance (International Organization for Standardization, 2022).

IoT technologies integrate medical devices into a unified network, making their management more effective. Through this technology, information about the technical condition of devices and their measurement results is transmitted to centralized information systems. IoT-based monitoring systems enable medical equipment to be tracked in real time and its technical performance to be assessed (Shaw & Gohel, 2025).

These systems automatically record the calibration status and technical parameters of devices. The use of IoT technologies not only improves the operational safety of medical devices but also helps optimize maintenance processes. In addition, this approach increases the efficiency of medical equipment management in healthcare institutions (International Organization for Standardization, 2022).

The use of digital calibration technologies is becoming increasingly common in modern metrological systems. Such systems automatically record measurement results and enable their prompt analysis. This approach minimizes the influence of human factors on the measurement process while helping to improve overall measurement accuracy. Digital calibration solutions support continuous monitoring of the metrological indicators of medical devices and make it possible to update and analyze calibration parameters automatically.

The measurement accuracy and functional reliability of medical devices are directly related to patients' health and safety. For this reason, the systematic and continuous improvement of the metrological characteristics of medical equipment is one of the priorities of modern healthcare systems.

The results of the study can be illustrated by the example presented below. The flowchart of the calibration process is shown in Figure 1.

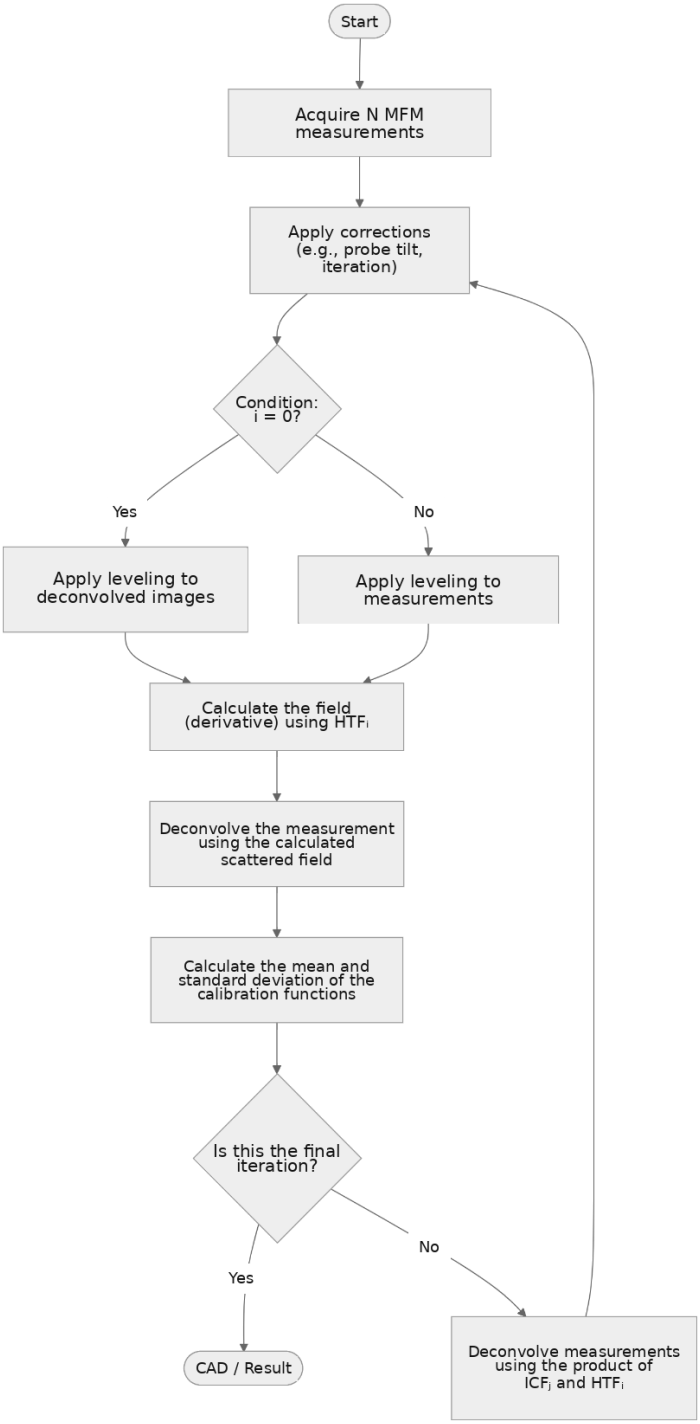

Figure 1
Flowchart of the calibration process

The calibration process is carried out through a staged and iterative approach intended to improve the accuracy of measurement results and ensure that the device correctly represents actual physical signals. The initial stage in the flowchart involves collecting MFM measurements. At this stage, several measurements are performed to create an initial dataset. However, the data obtained are not directly suitable for use because various systematic and random errors may arise during measurement. Therefore, corrections are applied at the next stage. These corrections include probe tilt, deviations arising from the technical characteristics of the device, and inaccuracies introduced during iteration (Taylor & Kuyatt, 1994).

One of the main characteristics of the process is its iterative nature. The decision blocks shown in the flowchart (for example, “j = 0” and “final iteration”) provide this repetition. During the initial iteration, measurements are processed directly; in subsequent stages, more accurate calculations are performed by taking the previous results into account. Leveling is applied to both the initial measurements and the deconvolved images so that all data are brought to a common reference level and can be compared.

At the next stage, magnetization structures are formed, and the field derivative is calculated on the basis of these structures. In this process, the HTF (Height Transfer Function) is used to establish a relationship between the measured signal and the actual magnetic field. The resulting field data are then used in the deconvolution stage. Deconvolution makes it possible to separate the instrument-specific characteristics and external environmental effects from the measurement signal, thereby enabling the actual physical signal to be reconstructed.

The results are then processed statistically. At this stage, the mean and standard deviation of the calibration functions are calculated, making it possible to assess the stability and reliability of the results. If the results do not meet the required level of accuracy, the process proceeds to the next iteration and the calculations are repeated. In the final stage, the measurements are deconvolved again, taking into account the combined effect of the ICF (Instrument Calibration Function) and HTF. This approach makes it possible to account for the instrument-specific characteristics and measurement conditions in an integrated manner, thereby aiming to achieve the highest possible accuracy.

Thus, all the stages presented in the flowchart operate in conjunction to minimize measurement errors and produce reliable results.

Selected Example Device: GE CARESCAPE Monitor B650
- Brand and model: GE Healthcare, CARESCAPE B650
- Measured parameters: SpO_2, ECG, temperature, NIBP
- Calibration instrument: Fluke Biomedical SPOT Light simulator
- Calibration software: GE CARESCAPE Calibration Tool
- Sensitivity level: SpO_2 ±2%, ECG ±0.5 mV

The calibration process is explained step by step below:
Preparation:
- The device is connected to a power source and switched on.
- The sensors are positioned correctly: a finger clip is used for SpO_2, and the ECG electrodes are applied to the chest.
- The calibration software is launched.

Testing with the Simulator:
- The Fluke SPOT Light simulator sends signals corresponding to the device parameters.
- The device readings are compared with the values generated by the simulator.

Adjustments and Optimization:
- Systematic errors are identified using the software.
- The parameters are automatically updated in the device memory.

The SpO_2 calibration results are presented in Table 2.

Table 2
SpO_2 calibration results

Test No.	Simulator result (%)	Device reading (%)	Error (%)
1	95	95.2	+0.2
2	90	89.9	-0.1
3	85	85.1	+0.1
4	80	80.0	0.0
5	75	75.2	+0.2

Analysis of results: The maximum error is ±0.2%; the device meets international standards.
The ECG calibration results are presented in Table 3.

Table 3
ECG calibration results

Test No.	Simulator result (mV)	Device reading (mV)	Error (mV)
1	1.0	1.01	+0.01
2	0.8	0.79	-0.01
3	0.5	0.51	+0.01
4	0.3	0.30	0.00

Analysis of results: The maximum error is ±0.01 mV; the ECG measurements meet clinical reliability requirements.

A graphical representation of the ECG calibration results is shown in Figure 2.

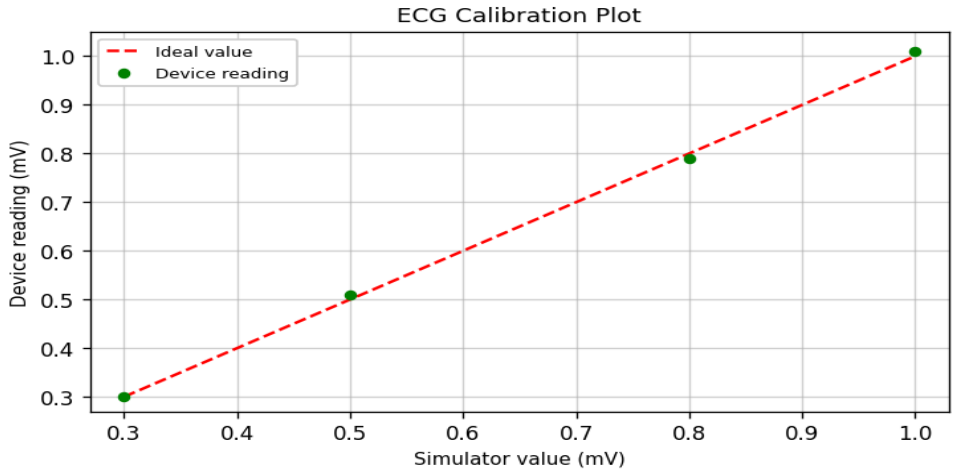

Figure 2
Graphical representation of the ecg calibration results

– X-axis: simulator values (mV)
– Y-axis: device readings (mV)

The analysis of the available scientific literature indicates that integrating modern technologies into the metrological assurance of medical devices is important for the development of healthcare systems. The use of sensor technologies, artificial intelligence algorithms, IoT-based monitoring systems, and digital calibration methods can increase the measurement accuracy of medical devices and improve their reliability (Kalantar-zadeh, 2013; Wilson, 2004).

Looking ahead, the wider application of artificial intelligence and Big Data technologies is expected to further improve the metrological characteristics of medical devices. These approaches may contribute to the optimization of measurement processes, more effective error detection, and an overall improvement in the quality of healthcare services (Joint Committee for Guides in Metrology, 2008; Cosoli et al., 2023).

Conclusions

1. The findings of the study show that metrological assurance, particularly calibration as one of its principal stages, is crucial to ensuring the measurement accuracy and reliability of medical devices.
2. Comparing measurement results with reference values, identifying systematic errors, and correcting them are essential conditions for ensuring the proper and stable operation of devices.
3. An iterative calibration approach, the use of deconvolution methods, and the application of calibration functions such as HTF and ICF make it possible to obtain measurement results with greater accuracy. In addition, statistical analysis methods enable the stability and reliability of the results to be evaluated.
4. The calibration results obtained from the selected medical device as a practical example indicate that properly organizing the process can produce highly reliable results. The identified measurement errors are stated to comply with the requirements of international standards and to confirm the device's suitability for clinical use.

References

Bohr, A., & Memarzadeh, K. (Eds.). (2020). *Artificial intelligence in healthcare.* Academic Press. https://doi.org/10.1016/C2018-0-04097-9

Bostani, R., Koleibi, E. R., Gagnon-Turcotte, G., Fontaine, R., Bhadra, S., & Gosselin, B. (2025). Readout techniques and offset compensation strategies for biomedical resistive MEMS sensors: A comprehensive review. *IEEE Reviews in Biomedical Engineering*. Advance online publication. https://doi.org/10.1109/RBME.2025.3639404

Chen, Z., Peng, B., Zhou, Y., Hao, Y., & Xie, X. (2024). A data-driven online calibration method for enhancing accuracy in biomedical tactile sensing. *Measurement, 236,* Article 115048. https://doi.org/10.1016/j.measurement.2024.115048

Cosoli, G., Antognoli, L., & Scalise, L. (2023). Methods for the metrological characterization of wearable devices for the measurement of physiological signals: State of the art and future challenges. *MethodsX, 10,* Article 102038. https://doi.org/10.1016/j.mex.2023.102038

International Organization for Standardization. (2022). *Medical laboratories—Requirements for quality and competence* (ISO Standard No. 15189:2022). https://www.iso.org/standard/76677.html

Joint Committee for Guides in Metrology. (2008). *Evaluation of measurement data—Guide to the expression of uncertainty in measurement* (JCGM 100:2008). https://doi.org/10.59161/JCGM100-2008E

Kalantar-zadeh, K. (2013). *Sensors: An introductory course*. Springer. https://doi.org/10.1007/978-1-4614-5052-8

Morris, A. S., & Langari, R. (2016). *Measurement and instrumentation: Theory and application* (2nd ed.). Academic Press. https://www.sciencedirect.com/book/9780128008843/measurement-and-instrumentation

Rabus, H., Agarwal, N., Boubekki, A., Bozkurt Varolgüneş, Y., Clark, B., Elster, C., Faller, J., Hegemann, N., Haufe, S., Heidenreich, S., Kapsch, R.-P., Kofler, A., Kolbitsch, C., Märtens, A., Martin, J., O'Connor, G., Panknin, D., Pfeffer, O., Pojtinger, S., Zimmermann, F. (2025). Metrology for artificial intelligence in medicine. *Measurement: Sensors, 38*, Article 101789. https://doi.org/10.1016/j.measen.2024.101789

Shaw, L., & Gohel, H. A. (2025). Role of artificial intelligence in health monitoring using IoT based wearable sensors: A survey. *Internet of Things, 34*, Article 101761. https://doi.org/10.1016/j.iot.2025.101761

Taylor, B. N., & Kuyatt, C. E. (1994). *Guidelines for evaluating and expressing the uncertainty of NIST measurement results* (NIST Technical Note 1297). National Institute of Standards and Technology. https://doi.org/10.6028/NIST.tn.1297

Wilson, J. S. (2004). *Sensor technology handbook*. Elsevier. https://shop.elsevier.com/books/sensor-technology-handbook/wilson/978-0-7506-7729-5

Journal of Technology Studies
November 2026, Volume: 3, Issue: 4, pp. 30–33
DOI: https://doi.org/10.36719/3104-4735/6/30-33

Human Resource Management in the Era of Digital Transformation: the Impact of Cloud Technologies and HR Analytics on the Decision-making Process

Gulpari Ergin

Abstract. *This study comprehensively examines the evolution of Human Resource Management (HRM) systems in the context of digital transformation, the application of cloud-based HR information systems (HRIS, SaaS), and the impact of Human Resource Analytics (HR Analytics) on the strategic decision-making process. The primary objective of the research is to evaluate the mechanisms of transition from traditional reactive personnel administration to a proactive, data-driven HR management model. The article analyzes the role of Big Data in predicting turnover, talent acquisition, and performance optimization within a sociotechnical and economic-analytical framework. During the study, international and local scientific literature from the last 5–10 years was compared, reviewing the contributions of cloud technologies to organizational agility. Alongside high efficiency indicators generated by digitalization, ethical management issues such as fostering a data culture, cybersecurity, data privacy, and algorithmic fairness are systemically summarized. The findings reaffirm the strategic role of HR professionals and the imperative to enhance their analytical competencies in a digital economy. It is demonstrated that in an innovative digital environment, the effectiveness of HR management significantly depends on the capabilities to collect, store, and deeply analyze large databases.*

Keywords: *human resource management, HR Analytics, digital transformation, cloud technologies, Big Data, strategic decision-making*

Introduction

The deepening of the Fourth Industrial Revolution and the rapid integration of digital technologies into the global business environment are fundamentally reshaping organizational management structures (Sadiqli, 2024). Among the domains undergoing the most significant transformation in this wave is Human Resource Management (HRM). Traditionally responsible for clerical tasks, administrative control, and record-keeping, HR structures in the modern era have evolved into strategic partners and major value-creating hubs within organizations. In the context of digital transformation, the effectiveness of HR management is directly linked to the capabilities for collecting, storing, and analytically processing large volumes of data. Cloud technologies (Cloud Computing / SaaS) and modern HR Information Systems (HRIS) facilitate the centralization of human resource data on a unified platform, ensuring real-time accessibility (Marler & Boudreau, 2017). Concurrently, making strategic decisions grounded in precise empirical data rather than subjective opinions through HR Analytics substantially enhances organizational productivity.

Azerbaijan University of Languages, Bachelor's Degree, Baku, Azerbaijan
Received: 28 May 2026; Accepted: 18 September 2026; Published online: 9 November 2026
E-mail: glprrgn06@gmail.com
© The Author(s) 2026. This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).

Research indicates that digitalization is not limited merely to the implementation of technological tools; it also demands the adaptation of organizational culture, management philosophy, and employee-employer relationships to the digital environment (Gahramanova, 2026; Gahramanova, 2026a). The efficiency of modern digital pedagogical and managerial tools depends on the humanistic and analytical evaluation of the human factor (Abdelkader et al., 2026). In this regard, investigating the impact of HR Analytics on decision-making mechanisms carries substantial scientific and practical relevance for Master's-level research in a digital economy. *Furthermore, as highlighted by Kuzior et al. (2022), "Digitalization of work and human resources processes serves as a critical path to sustainable enterprise development, fundamentally transforming traditional managerial approaches through advanced analytical frameworks" (p. 43). Thus, the transition toward cloud-based HR systems represents a fundamental shift...*

Methods

The methodological foundation of this research rests upon an interdisciplinary and systematic comparative analysis of scientific-theoretical literature published over the last 5–10 years on digital transformation and HR analytics. The study incorporates the following analytical methods:

1. *Systematic Literature Review and Content-Based Conceptual Analysis:* Academic articles covering the years 2017–2026 from WoS, Scopus, Google Scholar, as well as local journals (*Qadim Diyar*, *Elmi Ish*), were systemized along the vectors of HR digitalization, cloud technologies, and HR Analytics.
2. *Functional-Structural Modeling:* The functional architecture of cloud-based HRIS platforms (Workday, SAP SuccessFactors, BambooHR) across intra-organizational data flows and decision-making tiers was modularized.
3. *Comparative-Descriptive Analysis:* Traditional HR management methods were compared against data-driven HR analytics models regarding decision agility, cost optimization, and predictive accuracy indicators.

The empirical foundation of the study is shaped by secondary analytical indicators resulting from the implementation of digital HR platforms across various industry sectors.

Results

The analytical research reveals that digital transformation has shifted the role of HR departments from administrative execution to strategic business partnership. Modern HR Analytics manifests across three core developmental levels:

1. *Descriptive Analytics:* Ensures statistical reporting of current workforce metrics (turnover rates, attendance, training hours).
2. *Diagnostic Analytics:* Uncovers underlying root causes behind specific issues (e.g., drivers of employee voluntary attrition).
3. *Predictive Analytics:* Leverages artificial intelligence and machine learning algorithms to model future workforce requirements and turnover risks in advance (van den Heuvel & Bondarouk, 2017).

Table 1
The impact of Cloud technologies and HR analytics on decision-making processes

HR Technology / Platform	Core Functional Capabilities	Impact on Decision-Making Process	Primary Advantage
Cloud-based HRIS (SaaS)	Centralized workforce database, real-time data exchange	Eliminates administrative delays, enhances operational agility	Geographically unrestricted access and low infrastructure costs
Predictive HR Analytics	Turnover forecasting, risk mapping	Enables transition to proactive workforce planning	Reduces key talent attrition risk by 30-40%
AI-based Selection Tools	Automated CV screening, candidate evaluation	Shortens recruitment lead time, refines fit precision	Minimizes subjectivity in the selection process
Digital Performance Dashboards	Continuous visualization of KPI and OKR metrics	Objective, fact-based performance evaluation	Elevates employee motivation and transparency

Note. Compiled by the author based on systematic review of HR Analytics frameworks (2026).

Discussion

Scientific analysis demonstrates that while the application of HR Analytics and cloud technologies significantly boosts organizational efficiency, this transition is accompanied by strategic and ethical challenges. Notably, employee data privacy and cybersecurity issues come to the forefront during Big Data collection (Tursunbayeva et al., 2018). One of the most frequent hurdles in implementing HR Analytics is the insufficient development of a "data culture" within organizations. In many instances, HR professionals lack the quantitative and statistical skills required to operate analytical tools effectively (Angrave et al., 2016). This gap may lead to misinterpretation of collected data and erroneous strategic decisions.

Furthermore, the role of conceptual metaphors in digital media speech and managerial discourse shows that technological transitions require proper alignment of public opinion and organizational thinking (Gahramanova, 2026b). Placing the human element at the center of management and maintaining a humanistic approach remain paramount for the success of digital systems. As digitalization accelerates across organizations, accurately evaluating AI's semantic and syntactic adequacy levels constitutes an essential scientific mandate (Gahramanova, 2026a). The innovation wave driven by the Fourth Industrial Revolution indicates that HR Analytics is not merely a technical metric, but a strategic instrument shaping organizational economic growth (Sadiqli, 2024). Nonetheless, maintaining human oversight (human-in-the-loop) is imperative to mitigate algorithmic bias in hiring and performance appraisal processes (Davenport et al., 2010; Huselid, 2018).

Conclusion

This study on Human Resource Management in the digital transformation era allows for summarizing the following scientific-practical conclusions:

1. Cloud technologies and modern HRIS platforms alleviate administrative burdens for HR departments while enabling real-time, centralized data exchange.

2. HR Analytics liberates organizational decision-making from subjective biases, providing precise forecasting and fact-based strategic planning capabilities.
3. Successful digital HR transformation requires more than technological infrastructure investments; organizations must build a robust data culture, upscale the analytical competencies of HR staff, and deploy reliable cybersecurity frameworks.

References

Abdelkader, M., Zakariyya, S. S. A., & Ahmad, M. (2026). Gamma as a digital pedagogical tool enhancing student engagement, autonomy, and motivation in blended language learning contexts. *Elmi Ish*, *20*(6), 137–160.

Angrave, D., Charlwood, A., Kirkpatrick, I., Lawrence, M., & Stuart, M. (2016). HR and analytics: Why HR is set to fail the big data challenge. *Human Resource Management Journal*, *26*(1), 1–11. https://doi.org/10.1111/1748-8583.12090

Davenport, T. H., Harris, J., & Shapiro, J. (2010). Competing on talent analytics. *Harvard Business Review*, *88*(10), 52–58.

Gahramanova, F. (2026). Humanist approach in teacher-student relationships. *Qadim Diyar*, *8*(8), 33–38.

Huselid, M. A. (2018). The science and practice of Workforce Analytics: Introduction to the HRPS special issue. *Human Resource Management*, *57*(3), 679–684. https://doi.org/10.1002/hrm.21916

Kuzior, A., Kettler, K., & Rąb, Ł. (2022). Digitalization of work and human resources processes as a path to sustainable enterprise development. *Foresight and STI Governance*, *16*(2), 42–51. https://doi.org/10.17323/2500-2597.2022.2.42.51

Marler, J. H., & Boudreau, J. W. (2017). An evidence-based review of HR Analytics. *The International Journal of Human Resource Management*, *28*(1), 3–26. https://doi.org/10.1080/09585192.2016.1244699

Gahramanova, Y. (2026a). Impact of digitalization on language: AI's level of comprehension of semantic integrity and syntactic adequacy in language. *Qadim Diyar*, *8*(8), 115–121.

Gahramanova, Y. (2026b). Conceptual metaphors in political discourse: Mechanisms of shaping thinking and public opinion in digital media speech. *Qadim Diyar*, *8*(8), 7–15.

Sadiqli, K. (2024). Fourth industrial revolution: Shaping the future of economic growth and innovation. *Qadim Diyar*, *6*(3), 224–233. https://doi.org/10.36719/2706-6185/33/224-233

Tursunbayeva, A., Di Lauro, S., & Pagliari, C. (2018). People analytics—A scoping review of conceptual boundaries and research focus. *Personnel Review*, *47*(1), 224–247. https://doi.org/10.1108/PR-07-2017-0224

van den Heuvel, S., & Bondarouk, T. (2017). The rise (and fall?) of HR analytics: A study on the cadence of HR analytics adoption. *Journal of Organizational Effectiveness: People and Performance*, *4*(2), 157–178. https://doi.org/10.1108/JOEPP-03-2017-0022

van der Toren, P. W. (2022). Practical application of people analytics: A systematic review and research agenda. *Human Resource Management Review*, *32*(4), 100892. https://doi.org/10.1016/j.hrmr.2022.100892

CONTENTS

Ceyran Aghamaliyeva, Emin Janiyev
Design and Implementation of Smart Monitoring Systems Based on IoT Sensor Devices 5
Vusala Asadova
Science and Technology Enlightenment in "Fuyuzat" Magazıne: Sociolinguistic and Social-philosophical Perspectıves on Promotıng Ideas of Social Progress Through the Press in the Late 19th and Early 20th Centurıes 10
Hacı Beytullah Mutlu
Modern Water Purification Technologies: Integrated Treatment Processes and Sustainable Applications..... 15
Khayal Abdullayev, Elshad Mammadli
Application of New Technologies to Improve the Metrological Characteristics of Medical Devices..... 22
Gulpari Ergin
Human Resource Management in the Era of Digital Transformation: the Impact of Cloud Technologies and HR Analytics on the Decision-making Process..... 30

Signed: 04.11.2026
Online publication: 09.11.2026
Format: 60/84, 1/8
Stock issuance: 4 p.s.
Order: 246

It has been published on aem.az
Address: 19 A. M. Sharifzade St.,
Yasamal Dist., Baku, Azerbaijan
Phone: +994 50 209 59 68
e-mail: info@aem.az