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REVISED Nuclear energy terms formation in Azerbaijani language

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Abstract

The evolution of nuclear energy terminology in the Azerbaijani language reflects the broader dynamics of scientific development, language contact, and national identity. During the Soviet era, Azerbaijani scientific language was heavily influenced by Russian, the dominant medium for education and research. Following independence in 1991, Azerbaijan began a strategic linguistic transformation to align scientific terminology with the Azerbaijani language while maintaining compatibility with international standards. In recent decades, English has emerged as a critical source language, further shaping the modern terminological landscape.

This study employs a historical-linguistic approach to analyze terminology formation processes in Azerbaijani nuclear discourse. It draws on academic literature, institutional reports, and terminological databases to trace the adoption, adaptation, and standardization of nuclear terms. Particular attention is given to the influence of Russian and English as source languages.

The findings demonstrate a shift from Russian-dominated lexical borrowing to a more diversified system that incorporates English-based international terms and Azerbaijani-derived neologisms. Terminological formation methods include direct borrowing, calquing, and native coinage, supported by national institutions committed to linguistic standardization. The growing prevalence of English in international cooperation, technical documentation, and academic publishing has introduced new challenges and opportunities for terminological adaptation.

The formation of Azerbaijani nuclear terminology is an ongoing

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process that balances historical legacies with modern linguistic innovation. English now plays a significant role as a conduit for scientific advancement and global integration, complementing earlier Russian influences. To ensure linguistic coherence, scientific clarity, and effective communication across disciplines and public contexts, continuous collaboration between linguists, scientists, and policymakers is essential. The strategic development of national terminology will enhance Azerbaijan's capacity to participate in global.

Keywords
Nuclear terminology; Azerbaijani language; Scientific language development; Terminology standardization; Soviet influence Lexical borrowing; Calquing (loan translation); Neologism formation Language policy; International Atomic Energy Agency (IAEA); Post-Soviet linguistics;Technical translation; Radiation protection; National terminology infrastructure



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REVISED **Amendments from Version 1**

Since the previous version, this manuscript has been significantly revised to address reviewer comments, improve structural coherence, and enrich its analytical depth. The introduction has been expanded to incorporate broader theoretical and geopolitical perspectives, particularly drawing on the works of Igor Yegorov, Pál Tamás, and Jan Surman. These additions situate Azerbaijan's nuclear terminology development within the wider context of post-Soviet scientific transformation, language policy, and internationalization processes. The revised introduction now more clearly articulates the paper's relevance to both linguistic scholarship and science policy.

The methodology section has been substantially refined. It now provides a more transparent explanation of the criteria used to classify nuclear terms into categories such as direct borrowings, loan translations (calques), and neologisms. It also elaborates on the institutional role played by the Azerbaijan National Academy of Sciences, the State Committee on Terminology, and other academic bodies in shaping terminological decisions. The sources used for linguistic analysis—textbooks, technical manuals, and IAEA glossaries—are now described in greater detail, and the rationale for their selection is clearly stated.

In addition to structural improvements, the manuscript benefits from updated examples of Azerbaijani nuclear terminology to reflect modern usage and align with current regulatory and educational practices. The terminological examples provided in each section were reviewed, clarified, and, where appropriate, supplemented. Furthermore, the reference list has been updated to include recent scholarship and authoritative documents, such as the UNESCO guidelines on terminology policy.

Any further responses from the reviewers can be found at the end of the article

Introduction

The field of nuclear energy is a relatively modern scientific domain, emerging prominently in the 20th century with the development of atomic theory, nuclear reactors, and radiation technologies. These advancements revolutionized not only the scientific world but also had profound implications across industries, including energy production, medicine, military applications, and space exploration. As a result, a whole new lexicon of scientific and technical terms emerged globally to describe the complex processes and components associated with nuclear science[1].

In the Azerbaijani language, as in many others, the emergence and development of nuclear terminology followed closely behind the international evolution of nuclear science. The early formation of these terms in Azerbaijani was deeply influenced by historical, political, and cultural factors, particularly Azerbaijan's integration into the Soviet Union in the 20th century[2]. During this period, scientific and technical education was heavily centralized, and Russian became the primary language of instruction, research, and publication in higher scientific disciplines—including nuclear physics and engineering[3].

In recent decades, the internationalization of science has been extensively discussed, especially in the context of post-Soviet transformations. The development of nuclear terminology in the Azerbaijani language represents not only a linguistic shift but also a deeper reflection of geopolitical, institutional, and epistemic realignments in science after the collapse of the Soviet Union. Scientists such as Igor Yegorov and Pál Tamás have analyzed the changing structures of national innovation systems and the challenges of integrating into global scientific networks while maintaining national scientific identities[4]. These dynamics are especially pronounced in smaller post-Soviet states like Azerbaijan, where language planning intersects with efforts to rebuild and modernize national scientific infrastructures. Additionally, Jan Surman's work on Ukrainian science in the nineteenth century provides a valuable historical parallel, illustrating how scientific language choice and localization reflect broader questions of cultural sovereignty and intellectual independence[5]. By examining the Azerbaijani case, this paper contributes to these debates by showing how nuclear terminology formation is both a technical and symbolic process shaped by international pressures and national aspirations.

Consequently, much of the nuclear terminology in Azerbaijani was either directly borrowed from Russian or adapted from international scientific vocabulary that had already been integrated into Russian. These borrowed terms were gradually incorporated into the Azerbaijani scientific lexicon through academic publications, translated textbooks, technical manuals, and university curricula.

This article aims to explore the historical development of nuclear energy terminology in the Azerbaijani language, tracing its roots, identifying the main sources of lexical borrowing, and examining the linguistic mechanisms employed to integrate foreign scientific concepts. Additionally, it will discuss the transition period following Azerbaijan's independence in 1991, during which efforts to develop and standardize native scientific terminology gained momentum[6]. This analysis provides insights not only into the linguistic evolution of scientific language in Azerbaijan but also into the broader dynamics of language, identity, and modernization in a post-Soviet context[7].

Historical background

The formation of nuclear energy terminology in Azerbaijan cannot be fully understood without considering the broader context of international standardization and regulatory frameworks that have historically shaped national nuclear policies and scientific vocabularies. Scholars such as Geoffrey Rothwell[8] and John Samuel Walker[9] have shown how international safety norms, technical protocols, and institutional guidelines—particularly those developed by organizations such as the IAEA, the Nuclear Energy Agency (NEA), and national regulatory bodies—have driven the global harmonization of terminology in the nuclear sector. These standards have played a critical role not only in operational safety but also in shaping the linguistic codification of nuclear knowledge, especially in emerging nuclear states like Azerbaijan.

In this regard, Azerbaijan's post-independence efforts to standardize its nuclear terminology mirror broader international trends, where national regulatory systems increasingly align

their vocabularies with globally accepted norms. The translation and adaptation of IAEA glossaries, for instance, serve as more than linguistic exercises—they represent Azerbaijan's integration into a global epistemic regime governed by transnational safety standards and policy frameworks. This process also reflects what John Krige[10] terms the "managed circulation of knowledge," in which scientific expertise, documents, and standards are deliberately distributed through international institutions to reinforce shared norms and ensure regulatory convergence. In the Azerbaijani case, the adoption and localization of international nuclear terminology illustrate how knowledge flows are mediated by both linguistic sovereignty and compliance with global scientific governance. By engaging with these global structures, Azerbaijan's terminological development becomes a strategic act of both cultural assertion and international alignment.

The formation of nuclear energy terminology in the Azerbaijani language began in the mid-20th century, coinciding with the global emergence of nuclear science as a distinct and critical field. This development took place primarily during the Soviet era, a time when Azerbaijan was one of the republics of the USSR. Following the end of World War II, the Soviet Union prioritized the advancement of nuclear technology for both military and civilian purposes. This led to the rapid expansion of nuclear research institutions, scientific publications, and education across the entire Soviet bloc, including the Azerbaijan SSR.

During this period, the Russian language was the primary medium of scientific instruction and academic discourse throughout the Soviet Union. Most nuclear physics and engineering textbooks, research papers, and technical manuals were published in Russian. Consequently, Azerbaijani scientists, engineers, and students were introduced to nuclear concepts through Russian-language materials. As a result, the earliest nuclear energy terms to enter the Azerbaijani language were borrowed directly from Russian, often without modification[11].

The 1950s and 1960s marked a significant phase in the institutional development of nuclear science in Azerbaijan. The establishment of major scientific centers, such as the Institute of Physics under the Azerbaijan Academy of Sciences in 1945, laid the groundwork for research in nuclear physics, quantum mechanics, and radiometric methods.

One of the pivotal milestones in this era was the creation of the Institute of Radiation Problems in the 1960s, which focused on the peaceful use of nuclear energy and the study of radiation effects on materials and biological systems. The scientists working in these institutions were trained primarily in Russian and often collaborated with colleagues from other Soviet republics. As they translated or adapted Russian-language scientific texts for local use, a foundational vocabulary of nuclear terms began to take shape in Azerbaijani.

Furthermore, the Soviet education system in Azerbaijan played a critical role in the dissemination and normalization of nuclear terminology. Physics curricula in universities and technical institutes incorporated nuclear topics, and students became familiar with key terms through Russian-Azerbaijani bilingual instruction[12].

Methodology

The methodological approach of this study is based on a qualitative, historical-linguistic analysis designed to trace the formation and evolution of nuclear energy terminology in the Azerbaijani language. The research draws on a wide range of primary sources, including Azerbaijani-language textbooks in nuclear physics and radiochemistry, Soviet-era technical manuals in Russian, and translations of international documents such as the IAEA Safety Glossary[13]. Additional data were collected from official glossaries and dictionaries prepared by the State Committee on Terminology and the Azerbaijan National Academy of Sciences (ANAS)[14], as well as from internal materials of institutions like the Institute of Radiation Problems and the National Nuclear Research Center. These sources were chosen for their historical relevance and institutional legitimacy, and they reflect the formal transmission of nuclear concepts in both academic and regulatory settings.

To analyze the terminology found in these sources, the terms were grouped into three major categories: direct borrowings, loan translations (calques), and neologisms. Direct borrowings refer to words taken primarily from Russian or English with minimal phonological or morphological adaptation, such as reaktor, radiasiya, and izotop. Loan translations are terms that have been semantically translated into Azerbaijani while preserving the conceptual structure of the original expressions, such as *nüvə enerjisi* (nuclear energy) or *şüalanma dozası* (radiation dose). Finally, neologisms are newly created Azerbaijani terms that often result from institutional efforts to replace foreign borrowings with grammatically and culturally appropriate alternatives—examples include ionlaşdırıcı şüalanma (ionizing radiation) and dozometrik ölçmə (dosimetric measurement)[15].

For each term, a comparative etymological and semantic analysis was conducted to determine the source language, transmission path, and integration process into Azerbaijani. This included examining how borrowed terms were adapted to Azerbaijani grammar and phonology, whether their meanings shifted during localization, and how consistently they were used across disciplines such as nuclear physics, radiation protection, and nuclear medicine. Special attention was paid to the role of institutional actors—particularly terminology commissions, academic publishers, and regulatory agencies—in shaping and standardizing usage. In doing so, the study follows established approaches in terminology planning and the sociology of scientific knowledge, particularly as applied to smaller post-imperial states[4,7,10].

This methodological framework allows the paper to address not only the linguistic evolution of nuclear terminology in Azerbaijan but also its connection to broader institutional processes, such as the post-Soviet realignment of scientific governance and Azerbaijan's participation in global knowledge

networks. By combining textual analysis with historical context, the study highlights how terminology serves as both a technical and symbolic tool in the localization of scientific expertise.

Direct borrowing

The development of Azerbaijani nuclear energy terminology has been shaped by the interplay of several linguistic and historical factors. As nuclear science advanced globally—especially during the Cold War period—Azerbaijani scientists and institutions had to rapidly adapt to the evolving terminology. This resulted in a rich, layered vocabulary influenced by three primary sources: Russian, international (Latin and Greek), and older Islamic-world scientific traditions derived from Persian and Arabic.

The Russian language served as the primary conduit for the introduction of nuclear terminology into Azerbaijani during the Soviet era. From the 1940s onward, Azerbaijan's scientific development was deeply integrated into the broader Soviet system[14]. Most technical education, scientific publications, and research documentation were conducted in Russian, which led to widespread borrowing of terminology into Azerbaijani with little to no modification.

Key nuclear terms such as *reaktor* (reactor), *radiasiya* (radiation), *izotop* (isotope), *nüvə* (nucleus), and *enerji* (energy) were adopted into Azerbaijani primarily through Russian-language scientific materials, where the equivalents are *реактор, радиация, изотоп, ядро,* and *энергия*. However, it is important to note that these terms exhibit close phonetic and morphological resemblance not only to their Russian sources but also to their English and broader international counterparts. This is largely due to their shared etymological roots in Latin and Greek—reactor from Latin reactor, radiation from Latin radiatio, isotope from Greek *isos* and *topos*, and energy from Greek *energeia*. As such, these are part of a translingual scientific lexicon common to many modern languages. While the transmission pathway into Azerbaijani during the Soviet period was primarily Russian, the terminological forms remained largely consistent with international usage, particularly in the natural sciences. Although these terms were introduced into Azerbaijani via Russian during the Soviet era, their resemblance to English terminology is not coincidental. Most scientific terms in nuclear physics are internationalisms derived from Latin and Greek, and thus appear similar across multiple languages, including Russian and English. Their form in Azerbaijani reflects this global etymological lineage rather than a direct borrowing from English.

The dominance of Russian in higher education and academia created a standardized scientific vocabulary that persisted even after Azerbaijan gained independence in 1991. Even today, Russian-origin terminology remains prevalent in academic papers, textbooks, and technical manuals.

While many scientific terms came through Russian, their ultimate origin lies in the classical languages of science—Latin and Greek. These internationalisms, already standardized across many world languages, were seamlessly integrated into Azerbaijani scientific language due to their global ubiquity and the need for cross-disciplinary communication.

Examples include:

- *atom* – from Greek *atomos*, meaning "indivisible";
- *nütron* – neutron, from Latin/Greek roots (*neutro-* meaning "neutral");
- *proton* – from Greek *protos*, meaning "first";
- *elektron* – from Greek *ēlektron*, meaning "amber", related to electric charge.

These terms exhibit little to no morphological modification when used in Azerbaijani and are readily understood by scientists worldwide. Their use promotes international collaboration and ensures that Azerbaijani nuclear terminology is compatible with global scientific standards[13].

Furthermore, because many Latin- and Greek-derived terms entered Azerbaijani through Russian (and sometimes directly from Western European sources in the post-Soviet period), they serve as a bridge between local and global scientific communities.

Although Persian and Arabic did not directly contribute modern nuclear physics terminology, their influence is foundational in shaping the older scientific lexicon of Azerbaijani. These languages dominated scholarly discourse in the Islamic world for centuries, especially during the medieval period when Azerbaijani scholars such as Nasir al-Din al-Tusi contributed significantly to astronomy, physics, and mathematics.

Words such as:

- *elm* (science) – from Arabic *ʿilm*;
- *təhlükə* (danger) – from Arabic *ṭalḥuq* or Persian *tahlik*;
- *zərərli* (harmful) – from Arabic *ḍarar*.

These terms became deeply embedded in Azerbaijani through centuries of use in both religious and scientific contexts. In modern times, they have been employed in compound expressions and descriptive terminology for nuclear safety, risk management, and radiation protection, such as:

- *radiasiya təhlükəsizliyi* (radiation safety)
- *zərərli şüalanma* (harmful radiation exposure)

Thus, while Arabic and Persian do not directly contribute the technical core of nuclear terminology, they provide a rich lexicon of descriptors and modifiers that support the nuanced communication of nuclear concepts in Azerbaijani.

Calquing (Loan Translation)

In some cases, rather than borrowing entire words, Azerbaijani adapted compound Russian or international terms by translating their components literally. This process, known as calquing or loan translation, was especially common for descriptive

technical expressions that could be broken down into understandable native elements[15,16]. Calquing allowed the Azerbaijani language to internalize foreign scientific concepts without losing its syntactic and semantic identity. Instead of adopting foreign-sounding technical jargon wholesale, scientists and educators broke down the meanings of compound terms and reassembled them using native or previously localized components.

For instance, the term *nüvə enerjisi* (nuclear energy) combines *nüvə* (nucleus) and *enerji* (energy), both of which were already present in the Azerbaijani lexicon. Similarly, *şüa dozası* (radiation dose) is a direct semantic translation from Russian (*доза излучения*) or English (*radiation dose*), using *şüa* (ray or beam) and *doza* (dose). Other examples include *nüvə parçalanması* (nuclear fission), derived from the combination of *nüvə* (nucleus) and *parçalanma* (splitting or fragmentation), and *şüalanma səviyyəsi* (level of irradiation), which reflects a clear, structured translation of a scientific measurement concept.

This strategy of calquing served multiple functions. Firstly, it enriched the Azerbaijani scientific lexicon by creating a set of terms that could be easily expanded, adapted, and reused in different contexts. Because the constituent elements were drawn from the native language or widely accepted international terms, these calques were both technically accurate and linguistically accessible. Secondly, calquing preserved semantic transparency, making the terminology more intuitive for native speakers and more adaptable for educational purposes. This was particularly important in textbooks and classroom settings, where clarity and conceptual understanding were essential.

Thirdly, and perhaps most significantly, calquing promoted a sense of linguistic ownership over scientific knowledge. By expressing advanced nuclear concepts in terms that resonated with the Azerbaijani linguistic structure, calquing contributed to the broader effort of localizing science education and reducing the dependency on Russian or English in academic and technical communication. This process has become even more important in the post-independence era, as Azerbaijan seeks to strengthen its scientific infrastructure using its national language across research, education, and policy-making.

In recent years, calquing has also been supported by institutions like the Azerbaijan National Academy of Sciences and the State Committee on Terminology, which have encouraged the development of transparent, grammatically consistent, and culturally resonant scientific terms. These efforts aim to ensure that the Azerbaijani language remains a viable and modern vehicle for conveying complex technical knowledge, including in rapidly evolving fields such as nuclear science, radiation protection, and energy policy.

Neologism formation

Following Azerbaijan's independence in 1991, there was a renewed effort to assert national identity across all domains, including science and language. This political and cultural shift was accompanied by a broader linguistic renaissance aimed at de-Sovietizing the national lexicon and strengthening the role of the Azerbaijani language in education, research, and governance. One of the most visible aspects of this shift was the emphasis on creating neologisms—new words or phrases in Azerbaijani—to either replace borrowed terms from Russian or to describe previously unnamed scientific and technical concepts using native linguistic resources[11].

This neologism-building process was not arbitrary; it was supported by national institutions such as the State Committee on Terminology and the Azerbaijan National Academy of Sciences (ANAS). These bodies worked to ensure that the new terms were not only linguistically accurate but also understandable and practical for use in scientific communication, public education, and policy. In many cases, linguists and subject-matter experts collaborated to form terminologies that preserved scientific accuracy while resonating with Azerbaijani grammatical structure and cultural logic.

Several examples highlight the success of this approach:

- radiasiya təhlükəsizliyi (radiation safety) – a meaningful native compound phrase combining *radiasiya* (radiation) with *təhlükəsizliyi* (safety);
- nüvə tədqiqatları (nuclear research) – using native Azerbaijani words to denote domain-specific concepts;
- şüa mənbəyi (radiation source) – fully formed from Azerbaijani roots to describe a key concept in radiation physics.

These terms initially appeared in scientific textbooks, regulatory documents, and educational materials, reflecting the intent to make technical knowledge more accessible to Azerbaijani-speaking students, professionals, and the general public. The rise of Azerbaijani-language universities, media outlets, and technical publications in the 1990s and 2000s further accelerated the institutionalization and normalization of these neologisms.

In tandem with these linguistic developments, scientific and regulatory institutions began forming Azerbaijani equivalents for critical safety, measurement, and regulatory terms that were central to nuclear science, particularly in the context of radiation protection, dosimetry, and reactor monitoring. Among these were:

- şüa nəzarəti (radiation monitoring) – a localized term describing operational control of radiation levels;
- dozometrik ölçmə (dosimetric measurement) – referring to the precise measurement of absorbed radiation dose;
- ionlaşdırıcı şüalanma (ionizing radiation) – combining a newly introduced technical concept (*ionlaşdırıcı*) with native terms to represent the physics of radiation interactions.

These neologisms have since become part of the standardized technical lexicon used in Azerbaijani universities, government policy, radiation safety training, and translations of international documents, including those from the International Atomic Energy Agency (IAEA). More importantly, they contribute to the broader effort of linguistic sovereignty, enabling Azerbaijan

to communicate advanced scientific concepts through its national language without relying entirely on Russian or English terminology.

Terminological standardization

To ensure clarity and consistency across academic, scientific, and governmental contexts, terminological standardization became a national priority in Azerbaijan beginning in the early 2000s. Recognizing the fragmented state of technical vocabulary—especially in high-stakes fields like nuclear energy, radiation safety, and medical physics—the State Committee on Terminology of the Republic of Azerbaijan, in collaboration with the Azerbaijan National Academy of Sciences and leading universities, launched systematic initiatives aimed at unifying, regulating, and localizing scientific terms[17].

This standardization process was driven by several urgent needs: the necessity of maintaining coherence in education and research, aligning with international standards, and fostering national linguistic sovereignty in science and technology. A significant challenge was the presence of multiple variants for the same term in Azerbaijani scientific literature—some inherited from Russian, others from direct English borrowings, and some improvised locally. This inconsistency created obstacles in academic publishing, cross-disciplinary communication, and the translation of technical documents.

Key components of the standardization initiative included:

- Reviewing legacy terminology from Soviet-era publications and identifying outdated or inconsistent variants.
- Selecting and institutionalizing standardized forms of technical terms, giving priority to Azerbaijani equivalents where feasible.
- Publishing terminological dictionaries, glossaries, and electronic databases specifically tailored for fields such as nuclear physics, radiation medicine, and engineering, to be used by educators, researchers, translators, and regulatory agencies.
- Replacing non-standard or foreign-derived terms in official curricula, textbooks, and governmental documents with approved Azerbaijani alternatives.
- Coordinating terminology across adjacent disciplines—such as nuclear chemistry, radiation biology, and environmental science—ensuring consistent usage across regulatory frameworks, educational materials, and research outputs.
- Training linguists and subject-matter experts to collaborate in the evaluation and creation of terminological resources.

This initiative significantly improved the harmonization of language use across universities, research centers, regulatory bodies (e.g., the State Agency on Nuclear and Radiological Activity Regulation), and technical documentation. One important outcome was the facilitation of translations of international safety guidelines—particularly those issued by the IAEA—into Azerbaijani. This improved not only Azerbaijan's participation in global nuclear safety initiatives but also enhanced internal regulatory clarity and public communication in areas such as radiation protection, emergency preparedness, and environmental monitoring.

Furthermore, terminological standardization plays a strategic role in developing scientific literacy among Azerbaijani-speaking populations. By ensuring that technical terms are linguistically transparent and conceptually accurate, these efforts bridge the gap between expert communities and the broader public. They also reinforce the use of the Azerbaijani language as a viable and modern tool for expressing high-level scientific discourse, supporting national identity and innovation in a globalized scientific landscape.

Modern usage and challenges

Today, Azerbaijani nuclear terminology functions as a hybrid linguistic system, incorporating a blend of inherited Soviet-era vocabulary and increasingly localized Azerbaijani expressions. This hybridization is the result of both historical necessity and contemporary linguistic policy. On the one hand, many core technical and scientific terms—such as *reaktor* (reactor), *izotop* (isotope), *radiasiya* (radiation), and *nüvə* (nucleus)—were directly borrowed from Russian or from Latin-Greek internationalisms via Russian during the Soviet period. These terms were standardized across all Soviet republics and became deeply embedded in the educational system, research institutions, and public discourse in Azerbaijan.

On the other hand, Azerbaijan's independence in 1991 marked a turning point in the country's approach to language policy, including scientific and technical terminology. A growing national emphasis on linguistic sovereignty and cultural identity led to renewed efforts to adapt, refine, and standardize scientific language in accordance with Azerbaijani grammar, phonetics, and sociolinguistic norms. This included the coining of new terms, translation of international glossaries, and the promotion of Azerbaijaniequivalents in academic writing, educational materials, and public communication.

Today, terms such as

- *nüvə parçalanması* (nuclear fission),
- *ionlaşdırıcı şüalanma* (ionizing radiation), and
- *radiasiya təhlükəsizliyi* (radiation safety)

represent a conscious attempt to localize scientific language without sacrificing conceptual accuracy. Such expressions are often the product of collaboration between linguists and scientists, ensuring that the terminology remains intelligible to both specialists and the broader public.

This dual-layered vocabulary—combining international compatibility with national linguistic integrity—reflects Azerbaijan's broader goal of integrating into the global scientific community while preserving the cultural and linguistic uniqueness of the Azerbaijani language. Moreover, this hybrid model provides

practical advantages: it facilitates international collaboration and knowledge transfer, while also making complex scientific concepts more accessible to Azerbaijani-speaking students, professionals, and policymakers.

Efforts by institutions such as the State Committee on Terminology, the Azerbaijan National Academy of Sciences, and various universities have helped institutionalize this hybrid system. These bodies have published dictionaries, compiled technical glossaries, and implemented terminology standardization initiatives aimed at harmonizing language use across disciplines such as nuclear physics, radiation protection, and nuclear medicine.

Nonetheless, challenges remain. The ongoing influx of new scientific knowledge, particularly in areas like nuclear forensics, reactor lifecycle management, and small modular reactor technologies, continues to demand the creation or adaptation of terms. The goal is to strike a balance between scientific precision, linguistic clarity, and cultural relevance—an evolving task that requires continuous dialogue between domain experts and language professionals.

Azerbaijani nuclear terminology today is a dynamic and evolving system—one that mirrors both the historical legacy of the Soviet scientific paradigm and the future-oriented aspirations of a nation seeking to solidify its place in the international scientific community while cultivating a strong, autonomous linguistic identity.

Terminological consistency across disciplines

One of the key challenges in the use of nuclear terminology in Azerbaijan is ensuring consistency and coherence across various scientific and technical fields—such as nuclear physics, radiochemistry, radiation protection, nuclear medicine, and nuclear engineering. While these disciplines share a common foundation in nuclear science, each field has developed its own specific terminological preferences and frameworks over time. This divergence often stems from differences in institutional focus, educational traditions, and the sources of technical training materials used within each sector.

For instance, the term for a fundamental concept like "radiation dose" might be rendered as *şüalanma dozası* in radiological protection documents, while nuclear medicine practitioners may refer to it more commonly as *absorbsiyalı doza* or use clinical shorthand from international contexts. Similarly, terms like *reaktor nüvəsi* (reactor core) in nuclear engineering and *nüvə materialı* (nuclear material) in regulatory or nonproliferation settings may carry nuanced meanings depending on the context, potentially leading to misinterpretation or ambiguity if a standardized lexicon is not adhered to.

These inconsistencies can create serious complications, particularly in interdisciplinary collaboration, education, and regulatory communication. In educational institutions, students who study nuclear concepts in physics departments may encounter different terminology than those pursuing studies in medical physics or engineering. In regulatory and safety documentation, ambiguity in terminology can lead to misinterpretation of safety guidelines, inaccurate reporting, or inefficiencies in emergency response protocols. For instance, a radiochemist's definition of *aktivlik* (activity) may differ subtly in emphasis or usage compared to a nuclear power plant technician's understanding of the same term.

To address this gap, several institutions have taken important steps toward terminological harmonization. The Azerbaijan National Academy of Sciences (ANAS) and the State Committee on Terminology of the Republic of Azerbaijan have initiated projects to compile discipline-specific glossaries, review terminological usage in scientific publications, and develop standardized equivalents for frequently used nuclear terms. Some of these efforts have been published in specialized dictionaries.

However, this standardization process remains an ongoing challenge. As nuclear science evolves rapidly—especially with the introduction of emerging technologies such as small modular reactors, advanced radiopharmaceuticals, and digital dosimetry systems—terminology must also be updated regularly. Without a dynamic, centralized mechanism to review, validate, and disseminate new terminology, inconsistencies are likely to persist. Moreover, the increasing volume of scientific literature in English adds another layer of complexity, as many technical terms now enter Azerbaijani directly from English, bypassing traditional Russian intermediaries, which can create further variability in terminology.

For long-term success, Azerbaijan will need to strengthen interdisciplinary cooperation among scientists, linguists, educators, and policymakers. Establishing a national digital platform for terminology management, supporting terminological training for translators and educators, and embedding terminological standards into curricula and regulatory frameworks could significantly improve consistency, clarity, and the quality of nuclear science communication in the country.

Public-facing terminology and communication

Another significant challenge is the development of clear and comprehensible nuclear-related terminology for public communication, especially in areas involving nuclear safety, radiation exposure, environmental contamination, and health risks. While technical terms such as *şüalanma dozası* (radiation dose), *ionlaşdırıcı şüalanma* (ionizing radiation), or *radioaktiv çirklənmə* (radioactive contamination) are scientifically precise and well-established within expert communities, they often lack accessibility for non-specialist audiences. Most members of the general public—especially those without a background in physics, medicine, or engineering—find such terminology abstract, overly technical, or even intimidating.

This communication gap is particularly problematic in contexts where quick understanding is critical, such as during nuclear incidents, radiological emergencies, or the dissemination of public health guidelines involving radiation exposure (e.g., diagnostic procedures, cancer treatment planning). In such cases, the inability of the public to interpret key terminology may lead

to misinformation, unnecessary panic, or underestimation of actual risks.

To bridge this gap, there is a growing need to develop simplified, yet scientifically accurate terminology and explanations that can be effectively used in:

- Educational campaigns (e.g., school science curricula, awareness programs on radiation safety),
- Emergency response materials (e.g., instructions for radiological incidents or exposure protocols),
- Public health advisories (e.g., guidance on safe use of radiopharmaceuticals or routine diagnostics), and
- Media reporting (e.g., news coverage of nuclear-related developments or environmental assessments).

This is particularly important given the increasing civilian use of nuclear technologies in Azerbaijan and globally—such as:

- Medical diagnostics, including PET (Positron Emission Tomography) and CT scans that involve radioactive tracers;
- Radiation therapy in oncology departments, where patient awareness and consent depend on clear understanding;
- Industrial applications, such as non-destructive testing (NDT), where radiation sources are used in construction and materials science;
- Environmental monitoring, where radiation detectors assess contamination levels around mines, industrial zones, or former military sites.

Effective communication in these areas requires a multi-tiered strategy. This includes not only the creation of public-facing glossaries and outreach materials in plain Azerbaijani but also the training of educators, journalists, and emergency responders in basic nuclear literacy. Moreover, partnerships between linguists, nuclear experts, and communication specialists are essential to ensure that simplified terms preserve scientific meaning while remaining culturally and linguistically resonant with Azerbaijani speakers.

The digital media platforms and government portals can be used to disseminate interactive tools, infographics, and visual aids that explain complex nuclear terms using analogies, real-life examples, and clear language. Doing so can enhance public understanding, promote trust in nuclear institutions, and support informed decision-making in situations involving radiation risks.

Translating complex concepts into Azerbaijani

Translating and localizing highly specialized nuclear concepts into Azerbaijani presents a range of linguistic and conceptual challenges. Many terms used in nuclear physics, radiation protection, and nuclear engineering are deeply rooted in Western scientific traditions and often lack direct equivalents in Azerbaijani. These terms, commonly derived from Latin or Greek and widely used in English, Russian, and other global languages, require careful adaptation to ensure both linguistic compatibility and scientific accuracy.

The process of introducing these terms into Azerbaijani has involved various strategies, including direct borrowings, semantic calques, and, increasingly, the formation of native neologisms. However, effective localization goes beyond simple translation. It demands a multidisciplinary approach involving linguists, physicists, engineers, and educators to ensure that the resulting terms are both intelligible and technically correct. This collaborative model is supported by international best practices. For example, UNESCO's Guidelines for Terminology Policies emphasize the need for coordination between subject-matter experts and linguists to achieve sustainable and usable terminological systems, especially in smaller or post-colonial language communities[18].

In Azerbaijan, institutional efforts in this direction have been led by the State Committee on Terminology and the Azerbaijan National Academy of Sciences (ANAS). These bodies have promoted the development of scientifically valid and linguistically appropriate terminology, particularly through expert councils and national commissions. As noted by Hacıyeva[19] these committees have prioritized the harmonization of translated scientific terminology with Azerbaijani grammatical structures and semantic norms. For example, terms such as *ionlaşdırıcı şüalanma* (ionizing radiation), *nüvə sintezi* (nuclear fusion), and termal neytron (thermal neutron) were introduced not as direct borrowings but as structurally Azerbaijani terms crafted from internationally recognized roots.

Recent literature also supports this national approach to terminology modernization. For example, Surman[5] highlights how linguistic identity and scientific terminology are interlinked, especially in post-imperial and multilingual states. His analysis of nineteenth-century Central and Eastern Europe resonates with the Azerbaijani context, where terminological reform has accompanied broader efforts to assert scientific and cultural sovereignty in the post-Soviet era. Likewise, Krige[20] emphasizes that the global circulation of scientific knowledge is often structured by political and institutional forces, meaning that smaller states like Azerbaijan must actively engage in adapting and localizing international terms to preserve epistemic agency.

In practical terms, Azerbaijani terminology development has also been shaped by collaboration with international bodies such as the IAEA. The translation of the IAEA Safety Glossary into Azerbaijani, for instance, involved coordinated input from linguists and nuclear specialists to ensure terminological precision across regulatory documents, training manuals, and public health guidance[13]. This collaborative methodology aligns with the sociocognitive approach in terminology studies, which posits that scientific terms should reflect not only expert usage but also user comprehension and cultural context[21].

In summary, the translation of complex nuclear terms into Azerbaijani is not merely a linguistic task but a strategic process grounded in interdisciplinary collaboration, institutional policy, and international alignment. These efforts help ensure that scientific communication remains accurate, accessible, and aligned with national language development goals.

Growing need for national terminology development

As Azerbaijan increases its participation in nuclear energy applications across medicine, agriculture, industry, and research, the need for a robust and standardized national nuclear terminology base becomes more pressing[22]. The integration of nuclear technologies into various sectors demands not only technical expertise but also a linguistically precise and accessible framework to support communication, policy-making, and public awareness. This necessity is especially critical as the country moves toward greater self-reliance in scientific research, safety regulation, and international collaboration.

One of the key components of this development involves the localization of international nuclear safety standards, regulatory frameworks, and educational curricula. International organizations such as the IAEA provide comprehensive technical guidance on radiation protection, reactor operations, waste management, emergency preparedness, and non-proliferation. For Azerbaijan to align effectively with these standards, all relevant documents, protocols, and training materials must be accurately translated into Azerbaijani using consistent and standardized terminology. Inconsistent or overly technical translations risk misinterpretation, which can compromise both safety and regulatory oversight.

The several Azerbaijani institutions have initiated work to adapt and implement these standards. The Institute of Radiation Problems (IRP) plays a leading role in nuclear research and public radiation monitoring. The National Oncology Center is increasingly incorporating nuclear medicine into its research, particularly in areas such as radiopharmaceuticals, oncology diagnostics (PET and SPECT), and radiotherapy. Likewise, the Nuclear Research Department (NTD), established to oversee and advance national nuclear policy and research, has been actively participating in IAEA-coordinated projects and technical cooperation programs. These institutions contribute to the translation and dissemination of nuclear terminology in technical documentation, public education materials, and training resources. In parallel, modern methodology increasingly incorporates artificial intelligence (AI) instruments[23,24].

However, while institutional progress has been significant, broader interdisciplinary coordination is still needed to ensure linguistic, scientific, and regulatory alignment. Collaboration between linguists, subject matter experts, educators, and legal professionals is essential to develop terminologies that are not only technically accurate but also culturally and contextually appropriate. This is particularly important in high-stakes areas such as emergency communication, environmental risk assessment, and medical diagnostics, where clarity and public comprehension are paramount.

Furthermore, as Azerbaijan considers the potential deployment of nuclear research reactors or small modular reactors for peaceful energy generation, the importance of public engagement and education will grow substantially. Building societal acceptance of nuclear technologies requires not only technical transparency but also linguistic transparency—achieved through well-defined, consistent, and understandable terminology. This includes crafting public-facing materials, conducting outreach in schools and communities, and preparing clear communication strategies for risk scenarios or emergency response. The ability of the government and scientific community to communicate effectively with the public will directly influence the social license to operate future nuclear facilities.

Conclusion

The formation of nuclear energy terminology in the Azerbaijani language is the product of a complex interplay between historical, political, and linguistic factors. The initial wave of terminology emerged during the Soviet era, a time when Russian was the dominant language of science and higher education in Azerbaijan. As a result, many foundational terms in nuclear physics and engineering entered the Azerbaijani lexicon directly through Russian, often preserving their original structure and phonetics. These borrowings, in turn, were rooted in Latin and Greek etymologies, reflecting the global nature of scientific language development.

Over time, especially following Azerbaijan's independence in 1991, there has been a growing awareness of the need to adapt and refine scientific terminology to align more closely with the Azerbaijani language's phonological and grammatical structure. This shift has been driven not only by linguistic considerations but also by the broader cultural and political desire to strengthen national identity and scientific autonomy. Institutions such as the Azerbaijan National Academy of Sciences and the State Committee on Terminology have taken active roles in evaluating existing terms, creating localized equivalents, and promoting terminological consistency across academic disciplines.

Today, as Azerbaijan increasingly participates in international nuclear science initiatives—ranging from radiation protection and nuclear medicine to reactor technology and energy security—the need for a clear, standardized, and nationally coherent nuclear lexicon has become even more pressing. An effective and well-developed terminological system serves multiple functions: it facilitates scientific communication, enhances the quality of education and research, and ensures public understanding of nuclear technologies and safety protocols.

Moreover, the process of terminology development is not static; it evolves in parallel with scientific advancements, technological innovation, and societal needs. Azerbaijani experts are now contributing more actively to global nuclear discourse, necessitating the creation of terms for emerging concepts such as nuclear forensics, reactor life-cycle management, small modular reactors, and nuclear nonproliferation frameworks. This continued evolution requires close collaboration between linguists, scientists, educators, and policymakers.

In conclusion, the development of nuclear energy terminology in Azerbaijani is not merely a linguistic task but a strategic

endeavor with long-term implications for scientific progress, educational excellence, and national sovereignty. Building a precise, accessible, and unified terminological infrastructure will support Azerbaijan's aspirations to become a regional leader in nuclear research and innovation while ensuring that the language of science remains both globally connected and deeply rooted in the national linguistic heritage.

Ethics and consent

No ethics and consent were required.

Data availability statement

No data are associated with this article.

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Version 2

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William J. Nuttall
University of Bristol, Bristol, UK

I am reviewing a revised draft and I have sight of previous reviewers' comments on the first draft. I refer to those reviewers as reviewer one and reviewer two. I am grateful to the authors for the note about revisions since the first draft.

I can see that the comments of reviewer one have led to a strengthening of the paper, but I see that still the critique from reviewer two remains valid. Frankly the paper is still rather shallow and lacking in research depth. I further note that the text is rather repetitious in places, with the same ideas being presented two or three times.

For example:
Page 7, column 2, paragraph 3 is repetitious
and
Page 9, column 2, first paragraph is repetitious.

Removing repetition would allow for a shortening of the paper and facilitate the inclusion of new text. That could follow the advice of referee 2 strengthening the primary research credentials of the work.

Perhaps pragmatically, I suggest as an alternative that the work could have merit in the spirit of Briefing Article. In such a scenario additional ideas that could be brought in might include:

1. A much better description of the historical role of European classical languages in the history of science

2. A better appreciation of the emergence of nuclear energy terms. For example it is my anecdotal understanding that the term "reactor" took hold in nuclear engineering because it was chemical engineers from Dow Chemical who constructed EBR-1 at Argonne West in Idaho at the beginning of the industry. Up to that point nuclear reactors had been called 'piles'. Reactors were similarly

specified metal vessels in which chemical reactions were performed by chemical engineers in a pre-existing industry. I offer that anecdote by way of example - a research article would need to support similar claims with stronger evidence. I am not writing a research article here. I am merely saying how this article could dig deeper.

My main critique of the work (in the spirit of it perhaps being a briefing) is that there appears to be little, or no, critical thinking around the proposition that localisation of language is an unambiguously good thing. I can imagine arguments against localization, but such ideas are not presented.

For example: nuclear engineering is a safety critical business. In such an industry terminological uncertainty has the potential to cause, or exacerbate, accidents. To my impression the analogous area where such issues are most acute is in civil aviation. Prior to the breakup of the Soviet Union, Russian was the aviation language in the USSR, despite English being the wider international standard. The shift from Russian to English in the early 1990s is a rich and complex story largely seen through the lens of safety. The parallel is that one could perhaps argue that Azerbaijan should have moved from Russian to English without localization.

That logic, however, takes us to a follow on observation that is insufficiently considered in the work. The paper appears to refer more to the training of physicists than to the operation of nuclear industrial facilities.

In the USSR major industrial facilities would surely have operated under the Russian language, but I am no expert on such things

At this point I think it is relevant for me to point out that there is no history of civil nuclear energy in Soviet, or post-Soviet ,Azerbaijan. (There is nuclear power in neighbouring Armenia, but taking the logic in that direction would open a whole set of other issues.) The paper does not make clear that there is no nuclear energy system in Azerbaijan.

As the paper explains, there were, and are, a set of nuclear-interested institutions in Azerbaijan, but this reader would say that a more interesting post Soviet nuclear journey occurred in some other emergent states - including perhaps most notably Lithuania with its large power station and deep industrial research capabilities.

None of these issues around safety and the depth of the local nuclear enterprise are explored in the paper. The paper would be stronger if it made it clearer that the focus in Azerbaijan was not industry on a large scale, but rather education, research, specialist applications (e.g. medicine) and science.

Lastly, one argument in favour of localization is perhaps underplayed in the paper and that is the role of localized language in democratic oversight and control. Here one can refer to interesting developments in governance from Soviet era norms and constitutional structures.

There are arguments in favour of, and against, localization that do not appear in the paper - that is my real point here.

In summary, the paper reads well. My suggestion is the paper should have more substance. I offer

some suggestions in that regard, but I would also be happy to see the paper go in a different direction in search of substance - for example the direction recommended earlier by referee 2.

Because the paper could, and should, be strengthened, I do not recommend indexing at this stage. I recommend further improvement.

Is the topic of the essay discussed accurately in the context of the current literature?
Yes

Is the work clearly and cogently presented?
Yes

Is the argument persuasive and supported by appropriate evidence?
Partly

Does the essay contribute to the cultural, historical, social understanding of the field?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Energy Technology and Policy - especially in matters relating to civil nuclear power

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Version 1

Reviewer Report 14 June 2025

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The paper addresses the interesting topic of national developments in scientific language within an international context. By focussing on the history of the terminology used in nuclear energy research in Azerbaijani language, the author shows how a Russian dominated lexical slowly developed into a more English based set of terminology (including many Azerbaijani-derived

neologisms).

Although the author definitely addresses an interesting phenomenon, the paper does not really make clear what we can learn from this particular research as historians of science and internationalisation. As the author is probably aware of, there has been a lot of attention to the internationalization of science, also in post-Soviet states, over the past decades. For example, authors such as Igor Yegerov and Pal Tamas for recent post-Soviet developments, but also Jan Surman on Ukrainian science in nineteenth century offers an interesting reference.

In an even more broader context, it would be interesting to see the author position the paper in debates on the history of international standardization and regulation within the nuclear sector (e.g. Geoffrey Rothwell and John Samuel Walker). Also John Krige's work on the history of international knowledge distribution offers some potential ways to contrast the Azerbaijani case with relevant academic literature.

A second way to improve the paper would be to explain more about the methodology used for this research. Which sources were used to derive relevant nuclear terminology? And how were language connections established?

The first question needs to be answered since the paper aims to show an historical development without making explicit if the selected case-studies (and examples) are representative of the full-set of terminology that was used at that day.

The last question is especially relevant for the "direct borrowing" section where the author claims that the terms of *reactor, radiasiya, izotop, nüvə,* and *enerji* are directly borrowed from the Russian terms *реактор*, *радиация*, *изотоп*, *ядро*, and *энергия* while the terms actually seem to bear more resemblance with their English counterparts.

A final point for improvement would be to situate claims more within primary or secondary source material. For example, the section "translating complex concepts into Azerbaijani" does not include a single reference while several claims about the process of the creation of new terms such as the required need for collaborations between linguists, physicists, engineers and science educators. Is a requirement that was posed by the studied actors at the time or this a more general remark supported by secondary literature?

To finish, the paper does introduce us to an interesting case-study that potentially could learn us a lot about how scientific terminology is integrated within the context of nuclear research within "smaller" nation states, in particular in the post-Soviet context. However, the paper misses a thorough discussion on the relevant literature, does not elaborate on its methodology, and needs to improve situating its claims.

Is the topic of the essay discussed accurately in the context of the current literature?

No

Is the work clearly and cogently presented?

Partly

Is the argument persuasive and supported by appropriate evidence?

No

Does the essay contribute to the cultural, historical, social understanding of the field?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: History of Energy; History of Science; Business History; Environmental History; Public Administration

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 29 May 2025

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Azer Sadigov
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The article offers a valuable exploration of how nuclear terminology is developed and adapted within the Azerbaijani linguistic context. It highlights the historical influence of the Soviet period on scientific vocabulary and the ongoing efforts to nationalize and standardize terminology post-independence. The author classifies nuclear terms based on their origin—borrowed, calqued, or newly coined—and provides illustrative examples to show how literal translations can lead to ambiguity. While the paper is clearly structured and thematically relevant, its persuasiveness is limited by the absence of empirical data and practical validation. The lack of expert interviews, corpus analysis, or feedback from scientific users weakens the evidentiary support for the proposed terms. Nevertheless, the study makes a meaningful cultural and historical contribution by showing how scientific language reflects broader social and political processes. Strengthening the argument with comparative literature and stakeholder input would significantly enhance its academic and practical impact.

Recommendations:
1- The author should incorporate empirical evidence such as surveys, interviews with nuclear professionals, or analysis of terminology use in educational and regulatory documents to reinforce the validity of the proposed terms.
2- A comparative analysis with terminology development efforts in other Turkic or post-Soviet languages (e.g., Kazakh, Uzbek, or Georgian) would offer broader regional insight and highlight best practices applicable to the Azerbaijani case.

Is the topic of the essay discussed accurately in the context of the current literature?
Yes

Is the work clearly and cogently presented?
Yes

Is the argument persuasive and supported by appropriate evidence?
Partly

Does the essay contribute to the cultural, historical, social understanding of the field?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Nuclear physics, radiation materials, reactor physics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.