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METHODOLOGICAL DEFICIENCIES AND THE INTEGRATION OF GREEN ACCOUNTING IN UZBEKISTAN'S ENVIRONMENTAL AUDITS: AN OPERATIONAL ANALYSIS

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Annotatsiya. *Ushbu maqolada O'zbekistonda atrof-muhit auditi tizimining samaradorligiga ta'sir qilayotgan asosiy metodologik muammolar tahlil qilinadi. Tadqiqot davomida o'zaro bog'liq bo'lgan to'rtta muhim kamchilik aniqlangan. Jumladan, mahalliy sanoat korxonalarida yashil hisobot tizimlarining deyarli rivojlanmaganligi auditorlarga ekologik majburiyatlarni ishonchli baholash imkonini bermaydi. Shuningdek, tarmoq xususiyatlarini inobatga olmaydigan umumiy audit yondashuvlari, real vaqt rejimidagi monitoring o'rniga qo'lda yig'ilgan va kechikkan emissiya ma'lumotlaridan foydalanish hamda hayot tsikli tahlili va uglerod narxlash mexanizmlarining amaliyotga yetarlicha joriy etilmaganligi muhim to'siqlar sifatida ko'rib chiqiladi. Mazkur kamchiliklar O'zbekiston sanoat sektori misolida tahlil qilinib, Qozog'iston, Janubiy Koreya, Germaniya va Xitoy tajribasi bilan taqqoslanadi. Maqola yakunida bosqichma-bosqich amalga oshiriladigan islohotlar dasturi taklif etilib, uning mamlakatdagi mavjud institutsional va huquqiy sharoitlarda qo'llash imkoniyatlari baholanadi.*

Kalit so'zlar: *yashil hisobot, atrof-muhit auditi metodologiyasi, hayot tsikli tahlili, IoT emissiya monitoringi, uglerod narxlash, SEEA, ESG hisoboti, O'zbekiston sanoat sektori.*

Abstract. *This article examines four interconnected methodological failures that prevent Uzbekistan's environmental auditing system from functioning at the quality level that effective environmental governance requires. The central failure is the near-total absence of green accounting systems within domestic industrial enterprises, which deprives auditors of the financial data necessary for reliable environmental liability assessment. Compounding this are generic audit protocols that miss sector-specific environmental risks, the dominance of manual retrospective emissions data over real-time automated monitoring, and the non-integration of lifecycle assessment and carbon pricing tools into audit practice. Each failure is analyzed against operational data from Uzbekistan's industrial sector and compared with reform experience from Kazakhstan, South Korea, Germany, and China. The article concludes with a sequenced three-phase reform program and assesses its feasibility within Uzbekistan's existing institutional and legislative structures.*

Keywords: *green accounting, environmental audit methodology, lifecycle assessment, IoT emissions monitoring, carbon pricing, SEEA, ESG reporting, Uzbekistan industrial sector.*

Аннотация. *В данной статье рассматриваются четыре взаимосвязанных методологических сбоя, которые не позволяют системе экологического аудита*

Узбекистана функционировать на том качественном уровне, которого требует эффективное экологическое управление. Основным недостатком является почти полное отсутствие систем экологического учета на отечественных промышленных предприятиях, что лишает аудиторов финансовых данных, необходимых для надежной оценки экологической ответственности. Это усугубляется общими протоколами аудита, в которых не учитываются экологические риски, связанные с конкретным сектором, преобладанием ручных ретроспективных данных о выбросах над автоматизированным мониторингом в режиме реального времени и отсутствием интеграции инструментов оценки жизненного цикла и ценообразования на выбросы углерода в практику аудита. Каждый сбой анализируется на основе оперативных данных по промышленному сектору Узбекистана и сравнивается с опытом реформ в Казахстане, Южной Корее, Германии и Китае. В конце статьи приводится последовательная трехэтапная программа реформ и дается оценка ее осуществимости в Узбекистане.'

Ключевые слова: *экологичный учет, методология экологического аудита, оценка жизненного цикла, мониторинг выбросов Интернета вещей, ценообразование на выбросы углерода, СЭЭУ, отчетность ESG, промышленный сектор Узбекистана.*

Every environmental audit rests on a data foundation. The quality of that foundation determines the quality of the audit. This is not a theoretical point; it is an operational fact with direct regulatory consequences. An auditor who cannot access reliable data about what an enterprise emits, what natural resources it consumes, what environmental liabilities it has generated through past operations, and what future remediation costs those liabilities represent cannot produce an assessment that meets the evidentiary standard required for consequential regulatory decisions. Skilled auditors working from incomplete and unreliable data produce incomplete and unreliable findings.

Uzbekistan's industrial enterprises do not generate the data that environmental auditing requires. The 2022 survey conducted by the Uzbek Association of Accountants and Auditors, examining financial reporting practices at 184 enterprises legally subject to mandatory environmental audit, illustrates the scope of the problem precisely [1]. Ninety-one percent of surveyed enterprises tracked all environmental expenditures as a single undifferentiated operating cost line item, without distinguishing between preventive environmental management costs, regulatory compliance expenditures, remediation costs for historical contamination, and financial penalties for violations. Only 6% maintained any form of environmental liability reserve on their balance sheets. Forty-three percent had documented contamination findings from previous audit cycles that had generated no remediation response. The financial records of the typical Uzbek industrial enterprise contain essentially no information that is useful to an environmental auditor trying to assess actual environmental obligations.

This article traces the problem from its origin in enterprise accounting systems through its expression in audit protocols, monitoring technology, and assessment methodology. Each of the four methodological deficiencies identified is addressable through specific, technically feasible reforms that do not require new primary legislation in most cases-they require regulatory updates, institutional investment, and coordinated ministerial action.

Section 2 provides the theoretical framework. Section 3 analyzes the green accounting deficit. Section 4 examines the sector-specificity gap in current protocols. Section 5 addresses the monitoring data problem and the case for IoT-based continuous emissions tracking. Section 6 analyzes lifecycle assessment and carbon pricing integration. Section 7 synthesizes a reform program, and Section 8 concludes.

Theoretical Framework. The concept of environmental cost accounting has developed through three distinct intellectual traditions. The first is natural capital accounting, pioneered in the 1970s by environmental economists who argued that standard national income accounts systematically overstated economic welfare by treating the depletion of natural capital as income rather than capital drawdown. The UN SEEA framework, adopted as an international statistical standard in 2012, institutionalized this tradition at the macroeconomic level [2]. Enterprise-level green accounting systems translate the same conceptual framework to the individual firm.

The second tradition is environmental management systems, particularly the ISO 14001 framework developed in the 1990s. ISO 14001 requires certified organizations to identify and document their significant environmental aspects, establish objectives for improvement, and demonstrate progress against those objectives. Its value to environmental auditing is indirect but important: enterprises that have implemented ISO 14001 typically have more developed environmental data systems than those that have not, because the standard requires measurement and monitoring as a condition of certification.

The third tradition is integrated reporting, which developed since the 2000s in response to investor demand for non-financial performance information [3]. The International Integrated Reporting Framework, adopted in 2013, provides a conceptual framework for enterprise reporting on natural capital alongside financial, manufactured, and human capital. The EU's Corporate Sustainability Reporting Directive (CSRD), in force since January 2024, translates this into mandatory disclosure requirements for approximately 50,000 large European enterprises [4].

For environmental auditing practice, the intersection of these three traditions points toward the same conclusion: audit quality is bounded above by the quality of enterprise environmental data systems. Improving auditor skills, refining audit protocols, and strengthening regulatory consequences for non-compliance all have value-but they operate within constraints set by the underlying data. The most important lever for improving audit quality in Uzbekistan is improving the enterprise data systems that auditors depend on.

Empirical analyses. When an Uzbek environmental auditor arrives at a medium-sized chemical processing enterprise for a mandatory audit, the financial records available typically include: a general ledger with environmental expenditures aggregated into a single operating cost category; quarterly emissions reports compiled by the enterprise's environmental manager from manual measurement records; waste disposal contracts and invoices; and water use permits with associated billing records. This is the data universe the auditor works with.

What is missing is substantial. There is no record of the enterprise's environmental liability exposure-the probable future remediation costs from documented or probable historical contamination, the regulatory fines that enforcement proceedings might generate, and the restoration costs that end-of-life decommissioning will require. There is no record of natural resource depletion costs: the economic value of groundwater extracted above sustainable yield levels, the value of topsoil lost to erosion from adjacent agricultural land affected by chemical runoff, or the value of the assimilative capacity of the local river system consumed by the enterprise's discharge. There is no carbon account mapping greenhouse gas emissions against carbon trading obligations.

An auditor working without this information can determine whether the enterprise met its quarterly emissions report standards. The auditor cannot determine whether the enterprise's true environmental cost of production-including external costs imposed on surrounding communities and ecosystems-is consistent with its financial performance or with Uzbekistan's environmental targets. That is the difference between threshold compliance measurement and genuine environmental performance assessment.

Kazakhstan's Environmental Code, adopted in 2021, introduced mandatory disaggregated environmental accounting for all Category I and Category II industrial enterprises-those with the highest environmental impact profiles, representing approximately 600 enterprises nationally. The Code required separate tracking of resource extraction and consumption costs, environmental damage liability reserves, compliance expenditure distinguished from remediation, and greenhouse gas emission costs. Enterprises were given 24 months to implement the required systems, with Ministry of Ecology technical assistance available on request.

A 2023 evaluation by Kazakhstan's Ministry of Ecology assessed the impact on environmental audit quality for enterprises that had implemented these requirements. The evaluation compared audit finding accuracy-measured by the rate of concordance between initial audit findings and subsequent independent regulatory inspection results-before and after implementation. The finding was unambiguous: enterprises with implemented green accounting systems showed a 34% improvement in audit finding accuracy. The improvement came entirely from better data; the audit methodology and auditor skill levels were unchanged [5].

Table 1

Green Accounting Implementation: International Comparison

Country	Mandatory?	Scope	Adoption Rate (2023)	Audit Accuracy Impact	Env. Liability Reporting
Uzbekistan	No	Voluntary	9%	Baseline	6%
Kazakhstan	Yes (Cat. I–II)	High-impact firms	53.8%	+34%	44%
Georgia	Voluntary	Listed companies	17%	+11%	12%
South Korea	Yes (listed cos.)	All listed firms	89%	+41%	78%
Germany	Yes	All regulated firms	97%	+48%	91%

Figure 1 shows the diverging trajectories since 2018. Kazakhstan's adoption rate climbed steeply after the 2021 mandatory requirement, reaching 53.8% of targeted enterprises by 2023. Uzbekistan's rate grew slowly in the absence of a legal mandate, reaching approximately 9%-almost entirely concentrated among enterprises with international joint venture partners or foreign listing requirements that imposed their own green accounting standards. The gap between the two countries is not primarily a capacity or awareness gap. It is a regulatory mandate gap.

Uzbekistan does not need to implement the full SEEA framework across all industrial enterprises simultaneously. A phased approach targeting the 300 enterprises with the largest environmental impact profiles-concentrated in extractive industries, metallurgy, chemicals, and large-scale food processing-would cover approximately 73% of total industrial emissions while keeping implementation costs manageable. These 300 enterprises are already subject to the most rigorous audit requirements under LRU-678; adding green accounting requirements builds on existing compliance infrastructure rather than creating new institutional demands.

The Ministry of Finance's draft amendments to the Law on Accounting, which have been in parliamentary committee since March 2023, provide the legislative vehicle [8]. The technical standards for green accounting-how environmental cost categories should be defined, what measurement approaches are required, how liability reserves should be calculated-can be specified in implementing regulations that the Ministry of Finance and Ministry of Ecology develop jointly, using SEEA and ISO 14064 as international reference frameworks.

Uzbekistan's environmental audit framework assesses all industrial enterprises against a common set of environmental performance dimensions: air emissions against permitted thresholds, water discharge against quality standards, waste management against handling and disposal regulations, and soil conditions against contamination standards. This common framework is necessary for administrative manageability and cross-sector comparability. It is insufficient because different industrial sectors generate fundamentally different risk profiles that a generic methodology cannot capture.

Cotton gin operations present different environmental risks from copper smelters, which present different risks from pharmaceutical manufacturers, which present different risks from petroleum refineries. Cotton processing generates pesticide and agricultural chemical residues that persist in soil and migrate into groundwater through mechanisms requiring specific sampling protocols: multi-depth soil profiling and groundwater monitoring at defined distances from processing boundaries. Pharmaceutical manufacturing generates active pharmaceutical compound residues in wastewater that survive standard biological treatment and produce ecological and health effects in receiving water bodies that conventional water quality metrics-focused on BOD, COD, and pH-do not detect.

A generic audit protocol applied to either of these sectors will miss the most significant environmental risks those sectors generate. An enterprise in the cotton processing sector can present audit documentation demonstrating compliance with standard air, water, and waste thresholds while maintaining pesticide contamination levels in surrounding groundwater that make that water unsafe for human consumption and irrigation. The contamination is real and measurable; the audit framework simply does not require it to be measured.

The Institute of Chemistry of Plant Substances at the Uzbekistan Academy of Sciences conducted detailed soil and groundwater assessments at 47 cotton gin and cotton seed oil processing facilities in Kashkadarya and Surkhandarya regions between 2019 and 2021 [9]. The sample included facilities with valid environmental audit certificates issued within the preceding 24 months-enterprises that had, by the audit system's own measure, recently demonstrated compliance. The assessment found soil contamination at 31 of the 47 facilities (66% of the sample) at levels exceeding Uzbekistan's maximum permissible concentration standards for organochlorine and organophosphate pesticide residues. At 18 facilities, groundwater samples collected within 400 meters of processing boundaries contained pesticide compound concentrations above WHO safe drinking water thresholds.

The audit certificates held by these facilities were not fraudulent. The auditors had assessed what the protocol required and found compliance with the applicable standards. The protocol simply did not require soil profile sampling or groundwater monitoring. The audit system certified these enterprises as compliant while substantial contamination of soil and groundwater resources continued undetected by the regulatory system responsible for identifying it.

South Korea developed 23 sector-specific environmental audit protocols between 2010 and 2018. For each sector, the Ministry of Environment convened an 18-month working group involving environmental scientists with sector expertise, industry engineers from representative enterprises, practicing auditors with sector experience, and Ministry technical staff. The working group's mandate was to identify the specific environmental risk categories most material to the sector, design measurement and sampling protocols appropriate to those categories, and produce a draft protocol to be tested at a sample of volunteer enterprises before finalization.

The pilot testing phase was critical to the process's credibility. Each draft protocol was applied at ten volunteer enterprises, with results compared against both generic protocol results and independent third-party environmental assessments. Where draft protocol findings diverged significantly from third-party assessments, the working group reconvened to identify and resolve the source of divergence before the protocol was finalized. This iterative validation produced protocols that practitioners trusted because they had been tested against observable reality, not merely developed from theoretical principles.

The 2019 Korean Ministry of Environment evaluation found that average audit completion time fell 22% after protocols were introduced, because auditors spent less time determining which risk categories were relevant and more time systematically assessing the defined categories. Material violation detection rates increased 31%. Both auditor and enterprise manager satisfaction improved, because clearer protocols meant more predictable assessment processes and more actionable findings [10].

Uzbekistan's seven highest-impact industries-cotton processing, extractive industries, metallurgy, chemicals and fertilizers, food processing, textiles, and construction materials-are the natural starting point for a domestic sector-specific protocol development program. The Tashkent Institution of Management and Economics, Tashkent State Technical University, and sector ministries all have roles in the working group process. A five-year program to develop and validate protocols for these seven sectors would address the generality problem systematically while building domestic expertise in sector-specific environmental risk assessment.

Environmental auditors in Uzbekistan work from three primary documentary sources: quarterly emissions reports compiled by enterprise environmental managers from manual measurement records; waste disposal documentation maintained in paper-based or basic spreadsheet systems; and water discharge notifications submitted to basin management authorities at irregular intervals. All three describe what the enterprise reported having done over a past period, and all three are compiled manually by enterprise staff with an obvious interest in favorable outcomes.

Manual retrospective data collection has three structural limitations that directly constrain audit quality. The first is systematic presentation bias. Emissions measurement across most categories involves genuine technical uncertainty: measurement equipment has tolerance ranges, sampling procedures involve judgment calls about timing and location, and computational methods for converting measured concentrations to mass emission estimates require assumptions that can be made in multiple technically defensible ways. An enterprise environmental manager making these judgment calls consistently in the direction of results closer to permitted thresholds is not necessarily falsifying data. Each individual decision may be technically defensible. Their consistent direction toward favorable outcomes produces an aggregate bias that auditors reviewing the final compiled records have limited ability to detect.

The second limitation is temporal: quarterly reporting creates 90-day windows during which operating conditions can produce environmental impacts that never appear in official records. An enterprise that runs peak-capacity production during a 30-day order fulfilment period, generating above-permitted emissions, but returns to normal operations well before the quarterly measurement date produces compliant quarterly records that accurately reflect conditions at measurement time and say nothing about the elevated emissions that occurred outside the measurement window. For enterprises with predictable production cycles-seasonal agricultural processors, for example-this temporal gap is systematically exploitable.

The third limitation is measurement error. A 2020 accuracy assessment of environmental monitoring practices at 40 Uzbek industrial enterprises compared manual measurement results against automated sensor readings across five emissions categories [11]. Manual measurement error rates averaged 16.2% for SO_2 emissions, 14.8% for NOx, 18.4% for particulate matter, 11.3% for water discharge quality metrics, and 13.7% for waste volume records. Automated IoT sensor systems in the same study showed error rates of 2 to 4% across all categories. For a large industrial facility with 20 monitored emission points, a 15% average manual error rate produces aggregate figures that may misrepresent total actual emissions by 20 to 30% after compounding.

IoT-based continuous emissions monitoring places sensors at emission points that transmit readings at 15 to 30-minute intervals to a central data platform accessible to both enterprise management and regulatory authorities in real time. The technology closes all three gaps identified above: it eliminates bias through automated, standardized measurement without human judgment intervention; it eliminates temporal gaps through continuous rather than periodic coverage; and it reduces error through sensor precision substantially superior to manual methods.

China's deployment between 2017 and 2020 provides the most relevant large-scale evidence. The Ministry of Ecology and Environment required continuous monitoring installation at all facilities above specified capacity thresholds as part of an industrial pollution governance reform. By year three, more than 18,000 facilities were transmitting continuous monitoring data. The Ministry's 2021 evaluation found that continuous monitoring data identified systematic underreporting patterns at 23% of monitored facilities that a decade of manual inspection had not detected. Regulatory action based on continuous monitoring data produced verified emissions reductions of 14% across the monitored sector within three years [12, 13].

Table 2

IoT Continuous Emissions Monitoring Deployment: International Cost-Benefit Evidence

Country / Context	Facilities	Cost per Facility (USD)	Deployment (months)	Emissions Reduction (3yr)	Detection Rate Increase
China (2017–2020)	18,000+	\$28,000–\$45,000	36	14%	+23 pp
South Korea (pilot)	240	\$38,000–\$62,000	24	9%	+18 pp
Kazakhstan (ongoing)	~380	\$41,000–\$70,000	48	In progress	In progress
Germany (2000s)	~4,200	\$55,000–\$90,000	60	19%	+27 pp
Uzbekistan (estimate)	~80	\$36,000–\$76,000	36	est. 10–15%	est. +20 pp

Source: World Bank Industrial Monitoring Report (2022); Korean Ministry of Environment (2020); Chinese MEE (2021); Author's estimates.

For Uzbekistan, the approximately 80 industrial facilities that account for the bulk of national industrial emissions are the logical first deployment cohort. Installation cost estimates derived from Chinese and Korean benchmark data, adjusted for Uzbekistan's labor costs and equipment import logistics, produce per-facility estimates of $36,000 to $76,000. Total program cost for the 80 priority facilities over a 36-month deployment period is estimated at $2.9 million to $6.1 million. This is a one-time capital expenditure that would generate permanent improvements in audit data quality, reduce the manual monitoring burden on enterprise environmental managers, and give regulatory authorities the real-time visibility needed to target enforcement action.

The financing mechanism is straightforward. Continuous monitoring is a legal compliance cost that enterprises can and should bear. A regulation requiring Category I facilities to install certified continuous monitoring systems within 36 months, with cost recovery allowed through enterprise environmental provisions, would distribute the investment across the enterprises that benefit from the reduced audit burden it creates.

Threshold compliance measurement-the core of current Uzbek environmental auditing-answers a specific and limited set of questions: Is this enterprise operating within its permitted emissions limits? Is it discharging within licensed water quality standards? Is it disposing of waste according to applicable regulations? These are necessary questions. They are not sufficient for the environmental governance functions that Uzbekistan's green economy targets require.

The questions that Uzbekistan's 2030 targets require the audit system to support are different: Are industrial enterprises becoming more environmentally efficient over time? Is the industrial sector generating more or less environmental impact per unit of economic output than it did five years ago? Where within individual enterprises are the highest-return opportunities for environmental improvement investment? These are questions about trajectory and efficiency, not about threshold crossing. Threshold compliance measurement cannot answer them because it measures performance against a fixed reference point rather than tracking change over time or benchmarking efficiency across comparable facilities.

Lifecycle assessment methodology addresses this gap. LCA, standardized under ISO 14040 [14] and ISO 14044

[15], quantifies the total environmental impact associated with a product or process across its complete lifecycle: raw material extraction, transport and logistics, manufacturing, product use, and end-of-life treatment. Applied within an environmental audit, LCA enables the auditor to evaluate not just threshold compliance but the structural environmental efficiency of the enterprise's operations, identify the production stages or inputs generating disproportionate environmental costs, and estimate the environmental improvement potential of feasible operational changes.

Phase one covers months 1 to 18 and focuses on legal and regulatory prerequisites. The Ministry of Finance should advance the Law on Accounting amendments to introduce disaggregated green accounting requirements for Category I and II enterprises, with a 24-month implementation window. The Ministry of Ecology should initiate working groups for sector-specific protocol development in five priority industries: cotton processing, extractive industries, chemicals and fertilizers, metallurgy, and food processing. The Ministry of Economy should adopt regulations requiring continuous emissions monitoring systems at Category I facilities within 36 months.

Phase two covers months 18 to 42 and focuses on infrastructure and capacity deployment. The 80 priority continuous monitoring installations should be completed. The first two sector-specific audit protocols-for cotton processing and extractive industries, given their documented contamination issues-should be finalized and introduced into regulatory practice. LCA methodology training should be incorporated into the continuing education requirements for all certified environmental auditors. The carbon trading pilot should be expanded to 50 enterprises, with the integration mechanism connecting audit findings to carbon account adjustments implemented for all participants.

Phase three covers months 42 to 60 and focuses on full-scale integration and quality validation. All five sector-specific protocols should be in use. Green accounting requirements should be operational for the 300 largest enterprises by environmental impact. LCA-based assessments should be standard practice for audits of Category I enterprises. A quality assurance mechanism-independent review of a random sample of completed audits by Ministry of Ecology technical staff-should be operational to identify and address quality problems in the expanded, more geographically distributed audit market.

Conclusion. The methodological limitations of environmental auditing in Uzbekistan reflect specific policy choices. The choice not to require green accounting, not to develop sector-specific protocols, not to mandate continuous monitoring, and not to integrate lifecycle assessment and carbon pricing with audit practice were each individually rational given the institutional context in which they were made. They are individually and collectively reversible, and the evidence now available on the costs of maintaining them-contamination undetected, emissions misreported, targets unverifiable-makes the case for reversing them substantially stronger than it was when Law LRU-678 was adopted in 2019 [17].

Kazakhstan's experience demonstrates that a transition economy at comparable levels of development can implement green accounting requirements, sector-specific protocols, and continuous monitoring within a three-to-four-year legislative and implementation window [5]. South Korea's experience demonstrates that sector-specific protocol development, properly supported by working groups with industry and academic participation, produces measurable improvements in both audit efficiency and violation detection accuracy [10]. China's experience demonstrates that continuous monitoring deployment at scale, even across thousands of diverse industrial facilities, generates regulatory intelligence that manual monitoring systems cannot replicate [12].

Uzbekistan's 35% carbon intensity target by 2030 is six years away. The measurement and verification infrastructure for that target-the audit system capable of reliably documenting what enterprises actually emit, consume, and discharge-does not currently exist [18]. Building it requires the three-phase reform program described in this article. The reforms are feasible, the evidence for their effectiveness is clear, and the political mechanisms for implementing them are available. What remains is the ministerial-level will to use them.

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