MANAGEMENT OF WASTEWATER SYSTEMS IN SMART CITIES USING IOT TECHNOLOGIES

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Abstract: Effective wastewater management plays a critical role in removing contaminants from used water and enabling its reuse with minimal harm to the environment. With the growing environmental challenges faced by modern cities, there is an increasing need for advanced and intelligent wastewater treatment solutions. The integration of the Internet of Things (IoT) and wireless sensor networks offers a promising approach for developing such smart systems. This study proposes a conceptual model for a smart city wastewater management system (IoT-WMS) enhanced with blockchain technology. Blockchain is leveraged to securely store data and support a reward-based mechanism that promotes wastewater recycling. Tokens are distributed to households and industrial users based on the volume and quality of treated water. However, to prevent data manipulation aimed at unjustly earning these incentives, anomaly detection algorithms are employed to identify irregularities in IoT sensor data. The model utilizes smart sensors to continuously track wastewater generation and reuse. Simulation outcomes indicate high performance, achieving a 96.3% recycling rate, 88.7% system efficiency, 32.4% moisture content reduction, 90.8% increase in reuse, and 92.5% prediction accuracy.

Keywords: Internet of Things; wireless sensor networks; smart city; wastewater management

Аннотация: Эффективное управление сточными водами играет решающую роль в удалении загрязняющих веществ из использованной воды и обеспечении ее повторного использования с минимальным вредом для окружающей среды. С ростом экологических проблем, с которыми сталкиваются современные города, растет потребность в передовых и интеллектуальных решениях по очистке сточных вод. Интеграция Интернета вещей (IoT) и беспроводных сенсорных сетей предлагает многообещающий подход к разработке таких интеллектуальных систем. В этом исследовании предлагается концептуальная модель для интеллектуальной городской системы управления сточными водами (IoT-WMS), усовершенствованная с помощью технологии блокчейн. Блокчейн используется для безопасного хранения данных и поддержки механизма вознаграждения, который способствует переработке сточных вод. Токены распределяются среди домохозяйств и промышленных пользователей на основе объема и качества

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очищенной воды. Однако для предотвращения манипулирования данными, направленного на несправедливое получение этих стимулов, используются алгоритмы обнаружения аномалий для выявления нарушений в данных датчиков IoT. Модель использует интеллектуальные датчики для непрерывного отслеживания образования и повторного использования сточных вод. Результаты моделирования указывают на высокую производительность: коэффициент переработки составил - 96,3%, эффективность системы - 88,7%, снижение содержания влаги - 32,4%, увеличение повторного использования - 90,8% и точность прогнозирования - 92,5%.

Ключевые слова: Интернет вещей; беспроводные сенсорные сети; умный город; управление сточными водами.

Annotatsiya: Oqava suvlarni samarali boshqarish ishlatilgan suvdan ifloslantiruvchi moddalarni olib tashlash va uni atrof-muhitga minimal zarar etkazgan holda qayta foydalanish imkonini berishda muhim rol o'ynaydi. Zamonaviy shaharlar duch kelayotgan ekologik muammolar ortib borayotgan bir paytda, oqava suvlarni tozalashning ilg'or va aqlli yechimlariga ehtiyoj ortib bormoqda. Narsalar Interneti (IoT) va simsiz sensorli tarmoqlarning integratsiyasi bunday aqlli tizimlarni ishlab chiqish uchun istiqbolli yondashuvni taklif etadi. Ushbu tadqiqot blokcheyn texnologiyasi bilan takomillashtirilgan aqlli shahar oqava suvlarini boshqarish tizimi (IoT-WMS) uchun kontseptual modelni taklif qiladi. Blockchain ma'lumotlarni xavfsiz saqlash va oqava suvlarni qayta ishlashga yordam beruvchi mukofotga asoslangan mexanizmni qo'llab-quvvatlash uchun ishlatiladi. Tokenlar uy xo'jaliklari va sanoat foydalanuvchilariga tozalangan suv hajmi va sifatiga qarab taqsimlanadi. Biroq, ushbu imtiyozlarni nohaq ravishda olishga qaratilgan ma'lumotlar manipulyatsiyasining oldini olish uchun IoT sensori ma'lumotlaridagi qoidabuzarliklarni aniqlash uchun anomaliyalarni aniqlash algoritmlari qo'llaniladi. Model oqava suv hosil bo'lishini va qayta ishlatilishini doimiy ravishda kuzatib borish uchun aqlli sensorlardan foydalanadi. Simulyatsiya natijalari 96,3% qayta ishlash tezligiga, 88,7% tizim samaradorligiga, 32,4% namlikni kamaytirishga, qayta foydalanishni 90,8% ga oshirishga va 92,5% bashorat qilish aniqligiga erishib, yuqori samaradorlikni ko'rsatadi.

Kalit so‘zlar: IoT; simsiz sensorli tarmoqlar; aqlli shahar; oqava suvlarni boshqarish

Introduction.

In recent years, the rapid growth of urban populations and industrial activities has significantly increased the volume of wastewater generated in cities. This surge presents a critical challenge to conventional wastewater treatment

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systems, which are often outdated, inefficient, and incapable of meeting the sustainability demands of modern urban environments. At the same time, the concept of smart cities - urban areas that leverage digital technologies to enhance the quality of life and promote sustainable development - has gained significant global momentum. Within this context, efficient and intelligent wastewater management has become an essential component of smart city infrastructure.

One of the most promising approaches to address this issue is the integration of the Internet of Things (IoT) into wastewater treatment and monitoring systems. IoT enables real-time data collection, remote monitoring, automated control, and predictive maintenance, all of which can drastically improve the performance, transparency, and sustainability of wastewater systems. Through the use of smart sensors and interconnected devices, city authorities and water management agencies can make data-driven decisions that optimize resource usage, minimize environmental impact, and reduce operational costs. Furthermore, the incorporation of blockchain technology adds a layer of security and transparency to IoT-based systems. Blockchain can be used to store sensor data immutably and to implement incentive mechanisms that encourage the reuse of treated wastewater. For instance, households and industries can be rewarded with digital tokens based on their contributions to sustainable wastewater practices. However, such systems are not immune to manipulation, and malicious actors may attempt to falsify sensor data for personal gain. Therefore, advanced anomaly detection algorithms are essential to safeguard the integrity of the system and ensure that incentives are distributed fairly.

This study proposes a novel conceptual framework for a smart, secure, and efficient wastewater management system for smart cities, combining IoT technologies with blockchain-based incentives and anomaly detection algorithms. The simulation results demonstrate the system's potential to significantly enhance water reuse rates, system efficiency, and predictive accuracy, thereby contributing to more sustainable and intelligent urban water management.

Proposed Model: IoT-Based Wastewater Management System (IoT-WMS)
The prospect of water shortages is worrying as population growth rises. This has sparked the notion of wastewater reuse and recycling. Sensors may therefore be used for processing and monitoring at various stages of wastewater management. A comprehensive literature survey leads the research for developing an IoT-WMS framework. The IoT-WMS concentrates on cloud security using blockchain technology for the intelligent wastewater management schemes followed by smart cities. This IoT-WMS proposes a trading system based on the use of blockchain rewards for wastewater recycling. Every household/industry in the smart city

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enables the IoT-based wastewater management strategy with sensors and actuators. The basic conceptual structure of the IoT in wastewater management for smart cities is shown in Figure 1. Figure 1 shows the wastewater management cycle with efficient cloud data visualization for decision making. The decision support system performs token (cryptocurrency) allocation to households/industries regarding the volume of recycled wastewater. Based on their requirement to reach a minimum threshold volume, households/industries later resell these tokens. In a smart contract, the guidelines for the token exchange are established. Data stored on a blockchain-enabled cloud give inviolable auditing. The smart contracts often provide an automatic tracking framework with a secure cloud. Supervised and unsupervised learning algorithms are used to detect the manipulation of information on wastewater recycling in IoT meters by individuals to ensure the robustness of this model. Effective home automation allows the best usage of water and thereby increases the performance of the water delivery system and its services. For anomaly identification, this study utilizes a polynomial regression analysis algorithm. This anomaly monitoring model has been implemented to detect theft in energy consumption power meters. The time-series data are the meter readings, so a sequential learning model has been considered in this work. The IoT helps gain access to knowledge and makes significant decisions by obtaining various sensor values such as soil moisture, water levels, etc.

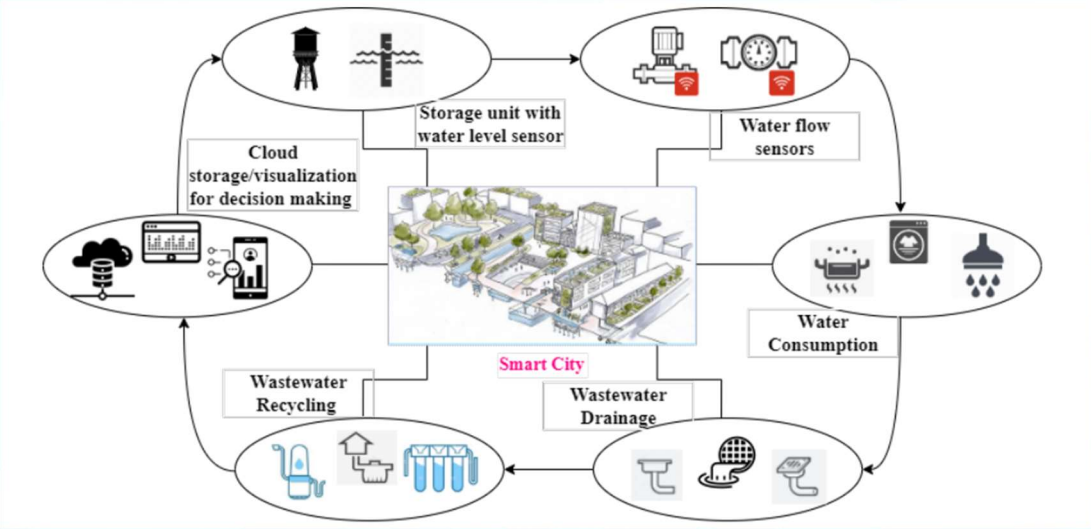


Figure 1. Domestic wastewater management cycle in smart cities.

Wastewater Management Architecture with Blockchain Technology: The smart wastewater management framework based on blockchain technology consists of five layers, as shown in Figure 2. The first layer, named the sensor layer, establishes the various IoT sensors for monitoring water usage and wastewater recycling. The data captured through these sensors are considered in the second layer called the data collection layer. In this layer, various industry/household

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facilities from layer 1, such as pipelines attached with level gauges, water meters attached water storage tanks, and smart wastewater treatment units fitted with IoT-based intelligent objects, are able to sense, track, analyze, acquire, and interact with data concerning the level of water storage, the quantity of water usage, the volume of wastewater generation, and its recycling volume. The gathered information is further transmitted to the third layer, the edge computing layer attached with edge nodes/smart gateways, through accessible internet services such as WiFi, 4G, and 5G for computation, decision making, collaborative filtering, and transient data storage over a preconfigured period of time. Using the edge nodes, the aggregated data items are validated through smart contracts and added to the blockchain. The edge nodes hand over the validated data units to the cloud server in the fourth layer: the wastewater blockchain located on cloudbased servers responsible for collecting, storing, processing, monitoring, and managing blockchain-technology-assisted security operations handling massive data produced from different IoT-enabled smart cities. In the fifth layers, frameworks for the management and monitoring of wastewater treatment for recycling and reuse are present. Through smart contracts, all parties interested in smart city wastewater management and monitoring are capable of querying the stored information in the blockchain-enabled cloud. For example, authorized people can access and visualize the data for decision making.

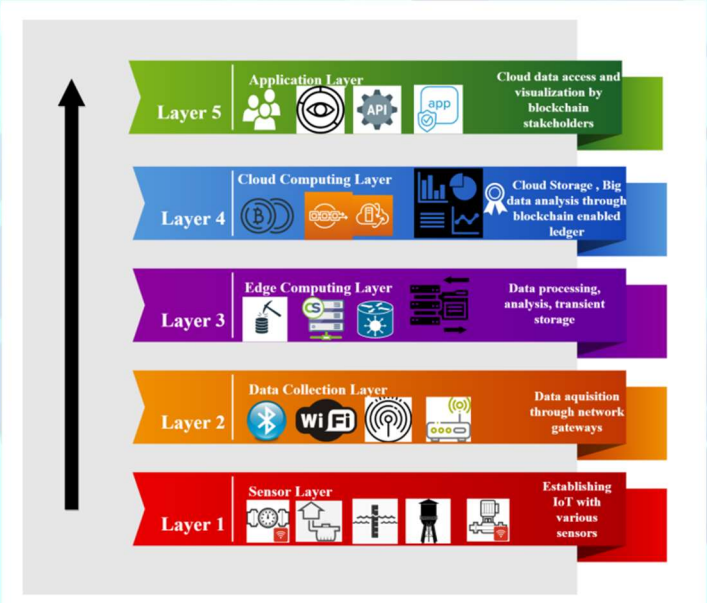


Figure 2. Architectural diagram of wastewater management with blockchain technology

Simulation Results and Discussion: The proposed IoT-WMS model monitors the recycled wastewater distribution in a smart city. Various parameters such as the wastewater recycling rate, the efficiency ratio, the moisture content ratio, the wastewater reuse ratio, and the prediction ratio have been considered

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using the proposed IoT-WMS method. The number of devices used for numerical simulations ranged from 5 to 30 in increments of 5. Each of these devices is assumed to have the capability of supporting up to 10 sensors. The simulation results averaged several random placements of sensors in a two-dimensional space. The devices are distributed in various stages of the wastewater management system, e.g., storage units, drainage units, recycling units, and water consumption units. A blockchain-based incentivization method is provided to various stakeholders in a model metropolitan area and its effect on the above parameters has been analyzed and compared with several existing approaches. Periodic monitoring of these parameters is performed using a cloudbased IoT system.

Conclusions. This study presents a conceptual framework for a smart wastewater management system (IoT-WMS) tailored for smart city applications, emphasizing data security through cloud infrastructure and blockchain integration. Based on an extensive review of recent literature, the proposed IoT-WMS incorporates a blockchain-driven incentive mechanism aimed at promoting wastewater recovery and reuse. By deploying smart sensors and actuators across households and industrial facilities, the system enables efficient real-time monitoring and control of wastewater treatment processes.

The simulation results demonstrate significant improvements over conventional wastewater management models. Specifically, the system achieved a 96.3% wastewater recycling rate, 88.7% operational efficiency, a 32.4% reduction in moisture content, 90.8% reuse of treated water, and a 92.5% accuracy in predictive analysis. These outcomes highlight the effectiveness of the proposed approach in enhancing sustainability and efficiency in urban water management.

However, the model does face certain limitations, particularly regarding scalability and interoperability when applied across diverse regions, such as multiple urban or rural municipalities. Additionally, the incentive framework would benefit from further development to enable cross-sectoral redemption of reward tokens, allowing broader participation from various industrial domains. Future research should explore the integration of deep learning technologies to further enhance the decision-making capabilities of the IoT-WMS, enabling more adaptive and intelligent wastewater management systems in smart cities.

REFERENCES

1. Al-Garadi, M. A., Mohamed, A., & Ali, I. (2020). **A survey of machine and deep learning methods for Internet of Things (IoT) security.** *IEEE Communications Surveys & Tutorials*, 22(3), 1646–1685. https://doi.org/10.1109/COMST.2020.2988293

ISSN 3030-3907

2. Zhang, C., & Liu, Y. (2021). **Blockchain-based data integrity verification and sharing for smart cities wastewater monitoring.** *Sustainable Cities and Society*, 70, 102881. https://doi.org/10.1016/j.scs.2021.102881
3. Farsi, M., Daneshkhah, A., Hosseinian-Far, A., & Jahankhani, H. (2020). **Digital Twin Technologies and Smart Cities.** *Springer International Publishing*. https://doi.org/10.1007/978-3-030-23180-7
4. Abegunde, L., Mahfouf, M., & Nandi, D. (2019). **IoT-based smart water quality monitoring system using wireless sensor network.** *Procedia Manufacturing*, 35, 657–662. https://doi.org/10.1016/j.promfg.2019.06.015
5. Kamel Boulos, M. N., & Al-Shorbaji, N. (2014). **On the Internet of Things, smart cities and the WHO Healthy Cities.** *International Journal of Health Geographics*, 13(1), 10. https://doi.org/10.1186/1476-072X-13-10
6. Shukla, M. K., & Thakur, A. (2021). **Role of IoT and Cloud Computing in Smart Wastewater Management.** *Materials Today: Proceedings*, 45(2), 752–757. https://doi.org/10.1016/j.matpr.2020.11.618
7. Piro, G., Cianci, I., Grieco, L. A., Boggia, G., & Camarda, P. (2014). **Information centric services in smart cities.** *Journal of Systems and Software*, 88, 169–188. https://doi.org/10.1016/j.jss.2013.10.029
8. Singh, R., & Kapoor, D. (2020). **Blockchain and IoT integration for secure and transparent smart wastewater management.** *IEEE Internet of Things Journal*, 7(5), 4043–4050. https://doi.org/10.1109/JIOT.2020.2969082
9. Hassan, N. U., Rehmani, M. H., & Chen, J. (2020). **Privacy and security in smart cities: Challenges and opportunities.** *Sustainable Cities and Society*, 61, 102251. https://doi.org/10.1016/j.scs.2020.102251
10. Rad, P., & Choo, K.-K. R. (2019). **IoT sensor data quality monitoring for wastewater treatment using machine learning.** *Future Generation Computer Systems*, 98, 522–533. https://doi.org/10.1016/j.future.2019.03.029

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