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Leveraging Blockchain Technology for Efficient and Transparent Waste Management in a Sustainable Ecosystem

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ABSTRACT: Traditional waste management systems which follows the traditional methods like land fillings, Incineration these methods will affect the environment, there will not have proper tracking systems, The disposing factor is not being done perfectly. In our project we will explore the key role of Blockchain and IOT. In block Chain it can provide traceability, Immutability, transparent and secure. IOT will be help to monitor the waste. The opportunities in Blockchain technology brings to waste management, including real time tracking, compliance with treatment laws, efficient resource management, secure documentation. This whole system makes the entire waste management process that promotes the transparency, traceability, reduces waste helps to protect the environment and promotes the use of recycling products.

KEYWORDS: Blockchain, IOT, QR code, Smart contracts

I. INTRODUCTION:

Blockchain is a decentralized digital ledger that securely stores records across a network of computers in a way that is transparent, immutable and resistant tampering. Each Block contains data, the data can be of different types such as images, videos, audios, text, files etc. but the most common use has been as a transaction-ledger, and these blocks are linked in a chronological order.

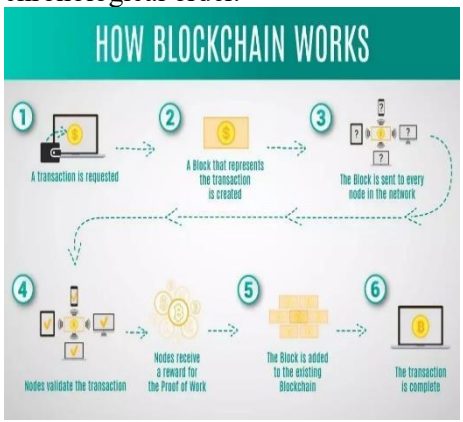

***Fig1:*Blockchain Architecture**

Using these benefits of the Blockchain, we can overcome the problems and addresses inefficiencies in traditional waste management which is lack of transparency and traceability and also while decomposing/disposing, it creates the environmental pollution from leachate and gas emissions, public health risks, inefficient resource recovery. These Challenges can be solved by implementing the block chain innovation in waste management.

Our proposed solution will operate the waste Collection, transportation, decomposition and recycling. In our solution, here every piece of trash will be having a unique identification

also tracks and make sure the recycling and decomposing process are working Correctly . In this system, people, who generates waste and are going to dispose the waste in an efficient manner will be rewarded and encourages the people to participate.

This whole system makes the entire waste management process that promotes the transparency, traceability, reduces waste helps to protect the environment and promotes the use of recycling products.

a. PROBLEM STATEMENT:

The system uses Blockchain and IOT-enabled smart bins to track waste from generators to decomposition units, ensuring transparency and efficiency. Waste is identified via QR codes, validated, and processed through recycling or safe disposal methods, with secure tracking to prevent environmental contamination. Recycled products support a circular economy, and eco-friendly practices like electric vehicles enhance sustainability.

S.NO	YEAR	AUTHORS	TITLE	KEY FINDINGS
1	2024	ABHIRAM KARUKAYIL et., al.	Deep Learning Enhanced Feature Extraction of Potholes Using Vision and LiDAR Data for Road Maintenance	• integrates LiDAR with RGB camera and models like YOLOv5, YOLOv6, • YOLOv7, and YOLOv8 were trained • integration of 2D and 3D data with • geo-positioning(GNSS)
2	2024	MALIK HASNAIN AHMED et., al.	Real-Time Driver Depression Monitoring for Accident Prevention in Smart Vehicles	• employing the VGG-16 model, for depression detection in drivers. • integrated with other technologies such as GPS, telemetry, and driver monitoring systems
3	2023	POOYAN KHOSRAVINIA, et.,al.	Enhancing Road Safety Through Accurate Detection of Hazardous Driving Behaviours With Graph Convolution Recurrent Networks	• presents a reliable DBD system based on Graph Convolution LSTM networks • deployed on Raspberry Pi at the network edge, a monitoring dashboard was built
4	2023	K. RAVEENDRA REDDY ,ANDA.MURALI DHAR	Machine Learning-Based Road Safety Prediction Strategies for Internet of Vehicles (IOV) Enabled Vehicles: A Systematic Literature Review	• decentralized ML technique is used in the context of IOV(Internet of Vehicles) • paper emphasizes how FL has the ability to overcome the drawbacks of centralized machine learning.
5	2022	ASANKA G. PERERA et.,al.	Road Severity Distance Calculation Technique Using Deep Learning Predictions in 3-D Space	• Deep learning and image processing and combine camera configuration data with a neural network detector to develop a distance vs pixel model. • We use camera metadata to transform the 2D image into a 3D space
6	2022	V. UMA MAHESWARI et.,al.	Driver Drowsiness Prediction Based on Multiple Aspects Using Image Processing Techniques	• methods such as EAR, MAR, • FAR,CNN ,EMOCDS ,NHTU-DDD • Detects the drivers drowsiness based on closed eyes, opened mouth while yawning .

7	2021	Khan Muhammad, et.,al.	Deep Learning for Safe Autonomous Driving: Current Challenges and Future Directions	• Advanced AI and DL approaches with a focus on road, vehicle, drowsiness detection, collision avoidance, and traffic sign detection through sensing and vision-based DL methods
8	2021	ALEXEY KASHEVNIK et.,al.	Driver Distraction Detection Methods: A Literature Review and Framework	• To reduce road accidents, detect driver inattention and distraction from used sensors, computed data, inferred behaviour for detecting the distraction types.
9	2020	QIWEI XU et.,al.	Research on Small Target Detection in Driving Scenarios Based on Improved YOLO Network	• adopts YOLO v3 end to-end network. • Detection accuracy is improved by 5.43% compared with that before the optimization.
10	2020	Kyle Sama. ,et.,al.	Extracting Human-Like Driving Behaviours From Expert Driver Data Using Deep Learning	• Deep learning techniques were used to extract latent features from the collected data. • Experimental results in a simulator implemented in ROS similarly to expert human drivers.

b. RESEARCH GAPS:

- The authors are using ML, CNN using deep learning for better classification of waste.
- In recent years the authors didn't propose a proper waste management system to collect the waste.
- In recent research, they are not providing rewards like tokens.
- In recent reviews, they are not charging penalty.

II. LITERATURE REVIEW:

- **MOHD HAFIZ BAHARUDDIN et.,al (2020).** In this article authors where proposed a smart waste management system using IOT sensors, LoRa and Tenser flow Based SSD Mobilnet V2 for waste classification and it is integrating real-time data monitoring.
- **ATTA UR REHMAN KHAN AND RAJA WASIM AHMAD**
- **(2022).**In this article authors proposed a Blockchain and IOT based system for secure and transparent E-Waste Management using a distributed ledger and IPFS for data storage. It is scalable, cost-effective, and adaptable to other waste management types.
- **BIN CHEN et.,al (2021).** In this article authors proposed a smart waste management system using IOT and MobileNetV3 for accurate waste classification and real-time monitoring. Future plans include multi-object recognition and rewards for proper waste disposal.
- **SAID GULYAMOVI et.,al (2024).**In this article the authors proposed that how IOT, Blockchain, AI, and data analytic can optimize waste management, reducing costs and emissions. Gradual testing and partnerships can help cities adopt smart waste systems sustainably.
- **MARIA ILARIA LUNESU et.,al (2024) .** In this article authors proposed that Blockchain enhances recycling by improving transparency and incentives, using a pizza box recycling case. It promotes community engagement and supports eco-friendly practices for small businesses.
- **Dr.R.CHITRA et.,al(2023).** In this article authors proposed that using Blockchain, smart contracts, and data encryption to ensure transparent, secure, and traceable e-waste management from collection to recycling. It prevents illegal dumping, promotes compliance, and benefits all stakeholders sustainably.
- **GAURAV THAKUR ET.,AL(2023)**This project integrates Blockchain and IOT to improve waste management with secure data storage, real-time monitoring, and reward-based smart contracts. It enhances efficiency, encourages proper disposal, and ensures transparency and traceability.

III. METHODOLOGY:

Blockchain is a decentralized digital ledger that securely stores records across a network of computers in a way that is transparent, immutable and resistant tampering. Using these benefits of the Blockchain, we can overcome the problems and addresses inefficiencies in traditional waste management which is lack of transparency and traceability and also while decomposing/disposing.

a. OBJECTIVES:

- To implement Advanced decomposing methods such as Araerobic Digesters, Composting Units for decomposing the waste.
- To develop the environment sustainable waste management system where it ensures the reliability, tamper-free ledgers.
- To Enhance the Hazardous waste handling ,which are used to Decompose the waste and produce recyclable products.
- Waste Generators are rewarded with tokens to encourage the public for the Environment Sustainability.
- IOT enabled Dustbins are used to notify the collectors and schedule optimized timings to collect the waste.
- Being socially responsible citizens, our project will decrease the pollution in the environment and proper disposing helps to decrease health issues by rewarding the public with tokens

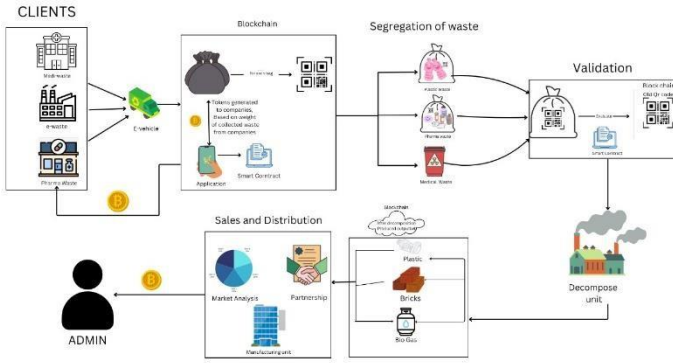

Fig2: **Architecture of Proposed System**

b. USED METHODOLOGY:

The proposed system is going to collect the waste from the waste generators such as e-waste generating industries, pharma waste, Medi waste from the hospitals etc., by the provided IOT enabled smart bins, which monitor the waste levels and can be used to schedule the optimized timings to collect the waste. The collected waste will be identified using unique identifier such as QR code, this QR code contains the waste type, origin of the waste, weight of the waste and so on., and the same data will be added to the block chain through the waste_Registration smart contract, and give the corresponding tokens to the waste generators based on the weight of the, the QR generated waste will be transported to the Decomposing units through the Electronic vehicles, which are eco-friendly.

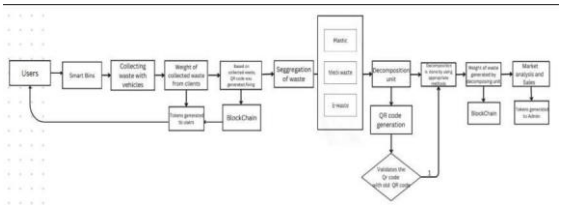

Fig3: **Algorithm of Proposed System**

At the decomposing units the waste bags will be validating such as checking through the QR code and the information in the block chain, if the waste got validated, then it will be proceeded with the further steps ,if not it will be returned back to the origin of the place. After getting validated ,the waste bags will be segregated or classified in to their respective waste type such as plastic, metals, e-waste, Medi waste. The plastic will be recycled by melting them and reshaping in to new products. E-waste will be dismantled and recover valuable metals such as gold, silver, copper, aluminium, steel and the rear metals such as indium, cobalt. The pharmaceutical waste will be decomposed through incineration with energy recovery systems, generating electricity, in specific conditions, some solvents or other chemicals used in pharmaceutical manufacturing or disposal processes might be recovered and reused. For the Medical waste these are disposed by Autoclaving method, where it uses high-pressure steam to sterilize waste, making it safe for disposal and Incineration. from this the recycled products will be limited , our main aim is to dispose them safely, we can recover Plastics(some non-contaminated plastics from packaging or medical devices can be recycled) and Metals(Metals from surgical instruments or other medical equipment can be recycled after sterilization).

Our system will be tracking e-waste through the recycling process, verifying the recovery of the specific products, for pharma and Medi waste system will track the secure and proper disposal of the waste to prevent the environment contamination. The recycled products will be sale in the respective market where it provides the circular economy.

***Fig4*:Work Flow of the Proposed System**

IV. RESULTS & DISSCUSSIONS:

Every transaction related to waste, from generation to final disposal or recycling, is permanently recorded on the Blockchain, creating an immutable audit trail. This provides unprecedented transparency and accountability. The proposed system allows for easy verification of recycling claims, reducing fraud and ensuring that recycled materials are genuinely from recycled sources. Real-time data and optimized routing lead to more efficient waste collection, reducing fuel consumption, vehicle wear and tear, and labour costs.

Automated processes through smart contracts reduce administrative overhead, paperwork, and manual errors. Verifiable recycling certificates can increase the market value of recycled materials, creating stronger incentives for recycling. Increased recycling and resource recovery help divert waste from landfills, reducing their environmental impact. Transparent tracking and accountability mechanisms help prevent illegal dumping and ensure proper handling of hazardous waste, reducing pollution. Optimized collection routes and reduced transportation needs contribute to lower fuel consumption and using E-Vehicles greenhouse gas emissions will be reduced. Citizens are more likely to participate in recycling and other waste management initiatives if they have confidence in the system

V. CONCLUSION:

The proposed system is potential of a Blockchain-based waste management system to transform the current practices by enhancing transparency, traceability and efficient. By leveraging Blockchain immutable ledger, IOT integration and smart contracts, the proposed system streamlines waste tracking, improved resource recovery. Through this promote trust among stakeholders and provides a circular economy, and contributors to a more, Sustainable future. Future research could explore advanced smart contract functionalities, integration with Al powered waste sorting and wider-scale implementation to maximize impact and scalability.

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