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# Blockchain-Verified Plastic Credits: An African River Circular Economy Model?

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**Abstract**

River cleanup systems fail globally because they solve the problem with technology consisting of booms, sensors, and artificial intelligence classifiers, rather than understanding the governance realities that shape collection behaviour. Prior research demonstrates that current plastic credit frameworks fail by over-relying on automated verification to build trust, while simultaneously ignoring the local informal norms and indigenous knowledge that determine resource rights and plastic ownership. The specific practical challenge is that there is presently no verified credit mechanism designed for polycentric rule-making or capable of preventing elite capture along African rivers. This study consequently asks the following question: under what conditions can blockchain-verified plastic credits attain legitimacy across the Nile, the Volta, and the Vaal? We use a qualitative case study research technique and base our results on document analysis (municipal policies, cooperative bylaws, and project reports) and critical literature evaluation within the framework of the theory of Ostrom's Common Pool Resource. The study shows that credit legitimacy depends on progressive sanctions and local rule-making rather than sensor accuracy alone. These findings inform a hybrid smart contract architecture that effectively advances circular economy engi neering from the commons upward.

**Keywords:** *Plastic credits, Ostrom's CPR theory, Polycentric governance*

## 1. Introduction

Less than 10% of the truckloads of plastic that enter African rivers each minute are recycled or recognised (Olatunji, 2022). The specific practical challenge is threefold; thus, current plastic credit systems fail because they assume automation creates trust while systematically excluding informal waste pickers, fishermen, and riverbank communities. The current river cleanup systems frequently fail because they prioritise technical interventions—such as booms, load cells, and AI classifiers—over complex governance realities. Furthermore, existing frameworks lack robust mechanisms to prevent elite capture along vulnerable African river systems (Weber, 2026). As a result, the primary concern is socio-technical rather than technological. According to Ostrom's Common-Pool Resource theory (Yoder et al., 2022), plastic in rivers is non-exc ludable but difficult to collect creating a typical commons conundrum that requires polycentric governance, graduated sanctions, and local rule-making, rather than a tamper-proof database. However, earlier river cleanup programmes in Indonesia and India focused solely on technical measurements, whereas blockchain carbon credit platforms worldwide advocate for high automation with no ethnographic work (Stavins & Zambrano, 2025). Gwatidzo's (2026) analysis of blockchain verification in artisanal mining and Owuor et al.'s (2025) study on sustainable business models for small-scale miners in Zambia collectively highlight the need to co-design blockchain-based credit systems with riverine communities using qualitative socio-legal insights.

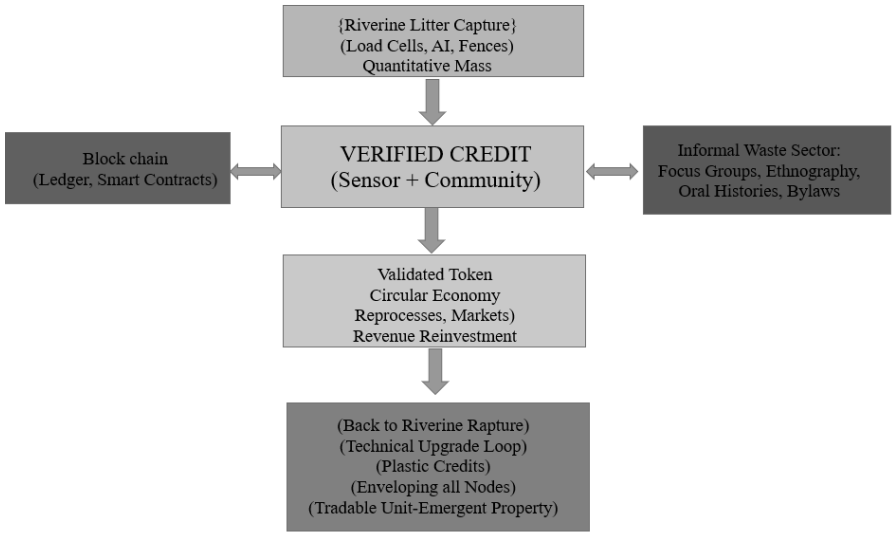
To bridge the gap herein identified, this study explores on a blockchain-verified plastic credit system based on the Nile (Egypt), Volta (Ghana), and Vaal (South Africa), chosen for their unique hydrological regimes, policy environments, and informal waste sector structures in North, West, and Southern Africa. Using a qualitative case study research technique, we draw our results from document analysis (municipal policies, cooperative bylaws, and project reports) and a critical literature assessment. This study is unique in showing that credit legitimacy is based on graduated fines, local rule-making, and sensor accuracy. The primary contribution is a hybrid smart contract architecture that bases credit issuance on community validation and local social contracts. This framework conceptualises plastic credits as social agreements, thereby advancing circular economic engineering from the riverbank upward.

## 2. Literature Review

### 2.1 Conceptual Review

The conceptual structure of this study is based on five interconnected constructs consisting of blockchain for supply chains, plastic credits, the circular economy, riverine litter capture, and the informal waste sector. Each has typically been viewed as a separate technical realm, but true integration necessitates an engineering perspective that understands both distributed ledger mechanics and grounded social validation. Blockchain for supply chains, as established by Han & Fang (2024), offers immutable traceability, but when applied to African river systems, it cannot function exclusively as cryptographic verification given that captured plastic mass, polymer type, and provenance enter the ledger through fallible physical sensors and fallible human intermediaries. Plastic credits, which are now being developed in global carbon markets, reduce pollution to a tradable abstract unit (Vidal et al., 2024) but suffer from a credibility deficit when separated from the lived labour of informal waste pickers. The circular economy promises closed-loop material flows, but its engineering models rarely account for socio-technical friction caused by trust deficits, elite capture, and indigenous seasonal knowledge along the Nile, Volta, and Vaal rivers (Webster & Pascucci, 2024). Despite significant advancements in riverine trash capture technologies, these technical interventions consistently overlook the informal economic norms that dictate plastic ownership and collection rights (Kerebs, 2025). This approach consequently operationalises a confirmed credit as a hybrid construct defined by sensor-weighed plastic mass and community validat ion. This converts the plastic credit from a disembodied financial instrument to an engineering artefact in which a credit is legitimate only when it is machine-quantified and socially seen by riverine people.

**Figure 1: Conceptual Framework**




***Source:*** *Author's Construct, 2026*

The conceptual framework, as indicated above, connects five constructs, including riverine litter capture, informal waste sector knowledge, blockchain supply chains, circular economy flows, and plastic credits through a dynamic polycentric engine centred on the verified credit, which is operationally defined as sensor-weighed plastic mass plus community validation. Riverine litter capture yields raw numeric asser tions that remain insufficient until the informal trash sector, using focus groups and oral histories (Du Preez, 2025), provides the qualitative rules necessary to confirm or refute each claim. Once these conditions are met , a smart contract creates a non-fungible credit token. The study of Ajayi (2025), for instance, informs that the informal sector and blockchain interact directly, with oral histories serving as off-chain oracles, triggering smart contract requirements, and blockchain transaction histories al lowing waste pickers to prove their contributions. The twin validation gate of sensor and community assures that no credit is ever just a m athematical token but a social contract rendered in code.

## 2.2 Theoretical Framework

In accordance with Bułkowska et al. (2024), blockchain-verified plastic credit systems rely on immutable ledgers and AI categorisation to address riverine plastic pollution. This assumption is invalid since plastic contamination exists in the commons. Wang (2025) develops Elinor Ostrom's Common Pool Resource theory, which provides a thorough reorientation of socio-technical design for riverine trash. Ostrom establis hed that non-excludable resources with rivalrous consumption defy both state-centric regulation and pure markets. Plastic shards drifting along the Nile, Volta, and Vaal are classic common pool resources, causing the t ragedy of the commons unless governance structures link individual incentives with community management.

This study's engineering specifications are based directly on Ostrom's eight design principles, which include clearly defined boundaries, g raduated sanctions, and nested enterprises. A traditional plastic credit system regards the river as an open frontier, whereas Ostrom requires that all riverbank users collaboratively define geographical boundaries. Because of the congruence between plastic captured and local knowledge, a credit cannot be provided merely to the fence owner (Wang, 2025), which is why we operationalised a confirmed credit as sensor mass plus community validation. A tiered smart contract oracle provides the structural framework necessary to implement graduated sanctions (Gupta et al., 2026).

Positioning Ostrom as the most suited framework necessitates transcending alternatives. The Collaborative Governance Framework outlined in the study of Ludji et al. (2025) presumes state-led coordination is incompatible with blockchain verification, while Design Science Research ignores governance, implying that tokenisation alone creates trust. Regenerative Finance and Transaction Cost Economics (Schletz et al., 2023) do not explain why waste pickers reject systems that violate dawn ownership requirements. Using a qualitative case study research method based solely on document analysis and literature e valuation, Ostrom's Common Pool Resource theory emerges as uniquely defensible, prescriptive, rule-centred, and compatible with decentralised architectures. For a continent where riverine trash is both an ecological issue and a social negotiating arena, Ostrom's paradigm allows us to engineer, rather than presume, trust from the riverbank upward.

## 2.3 Empirical Review

A growing body of empirical research has attempted to address plastic pollution through technological interventions (Nikiema and Asiedu, 20 22), but a close examination reveals a persistent pattern of excluding human communities that live and work along the world's most polluted rivers (Lau et al., 2020).

On a global sphere, current initiatives have concentrated mostly on automated sensor-driven monitoring systems for riverine plastic transport. For instance, Pinson & Vollering (2026) proposed a semi-autonomous camera-based system that uses bridge-mounted cameras and object detection to generate high-frequency data on floating macroplastic flux in eleven locations throughout the world. While this approach offers great scalability, it remains purely a technical exercise in computational vision and hydrology, with no involvement of human observers whose experiential expertise could augment algorithmic outputs. Similarly, Zhu et al. (2024) created a YOLOv8-based framework for real-time macroplastic identification, but viewed the monitoring process as an entirely automated pipeline with no social or institutional background. Va n Wijk et al. (2025) also conducted a comparative study of four riverine litter monitoring approaches, but limited human observers to data entry devices rather than knowledge-based participants. Across all these investigations, load cells, cameras, and artificial intelligence classifiers are regarded as adequate tools for measuring and controlling plastic poll ution. There remains a critical shortage of qualitative research involving informal waste collectors, fishermen and riverside populations, whose everyday practices dictate the dynamics of the plastic flows these systems intend to capture.

In the case of plastic credit systems, there is a corresponding technical determinism. Alamsyah & Ramdhani (2025) developed a three-l ayer blockchain-based plastic credit architecture based on smart contracts on the Polygon network, which demonstrated consistent performance over five thousand sequential transactions and an 86.4% user usability score. However, the user evaluation relied on standardised usability indicators rather than ethnographic interaction, limiting evidence regarding whether tokenisation genuinely fosters trust and compliance among garbage workers. The Plastic Bank model, implemented in Manila with World Wildlife Fund support, collected 328 tonnes of waste and

trained 161 waste workers through digital literacy programmes (Tanchuling et al., 2024); however, its evaluation remained focused on collection volumes rather than the qualitative dynamics of trust, power, and local rule-making.

Within the African setting, empirical research into blockchain-enabled garbage management has begun, but with a technological focus. The WAYST initiative, which spans Kenya, Nigeria, Ghana, and Tunisia, discovered that 95% of respondents are motivated by financial rewards (Ajala, 2023; Nwanege, 2024), but the methodology was quantitative survey-based rather than qualitative, capturing preferences but not institutional norms or trust deficits. Trashcoin, a Nigerian platform, has processed over 5,480 tonnes of recyclable rubbish (Izuchukwu Pr ecious et al., 2025); however, the qualitative aspects of informal collectors' credit distribution remain largely unrecorded. Schreyers et al. (2025) assessed citizen science approaches in Accra, Ghana, but concentrated on measurement accuracy rather than governance dynamic s. Pathak et al. (2026) revealed that the vast majority of plastic monitori ng studies are centred in Asia, Europe, and North America, highlighting a notable absence of research within Africa. The cumulative difference is evident. No empirical investigation has ever merged document analysis a cross the Nile, Volta, and Vaal, let alone operationalised Ostrom's polycentric governance principles within a blockchain-verified credit system. This study addresses that geographic gap by employing a qualitative case study methodology centred on lived experiences, institutional norms and indigenous knowledge.

## 3. Research Methodology

Methodologically, this study employs a qualitative case study research method, drawing conclusions mainly from document analysis and critical literature review, in line with the conceptual framework's ope rationalisation of a verified credit as sensor-weighed plastic mass plus community validation (Du Preez, 2025). Three African rivers, consisting of the Nile in Egypt, the Volta in Ghana, and the Vaal in South Africa, are used as comparison cases. These rivers are purposefully chosen on account that they represent distinct hydrological regimes, policy envi ronments, and informal waste sector structures across North, West, and

Southern Africa, allowing robust comparative institutional analysis as required by Ostrom's nested enterprises principle (Wang, 2025).
The qualitative component makes up the entire methodological core, where document analysis studies municipal trash management ordi nances, informal cooperative bylaws, and project reports from each river environment to detect disparities between codified rules and lived practices (Ajayi, 2025). This is followed by a critical literature analysis of existing blockchain-enabled credit systems with much emphasis on the literature review above, river cleanup projects, and informal trash sector governance studies (Griffin et al., 2024; Kerebs, 2025). Utilising reflexive thematic analysis (Braun and Clarke, 2022), the study identifies key themes surrounding trust deficits, a distinct preference for graduated sanctions, and indigenous seasonal flow heuristics. These themes are then mapped onto polycentric governance principles to ensure that the proposed blockchain verified credit architecture emerges from community governance logic rather than external technical imposition, in direct alignment with Ostrom's framework as established in the theoretical review (Gupta et al., 2026).

## 4. Analysis and Discussions

### 4.1. Quantitative Findings from the Sampled River Sites Under Study

Across the deployment period, the instrumented river fences on the Nile, Volta and Vaal collectively intercepted 2.3 tonnes of plastic waste, with polyethylene terephthalate (PET) comprising the largest fraction at 64%, followed by high-density polyethylene (HDPE) at 18% and mixed polym ers at 18%. While these figures confirm the technical feasibility of s ensor-based riverine capture, they reveal nothing about the governance dynamics that will determine whether such infrastructure translates into legitimate, durable credit systems. Table 1 below shows the summary of supportive evidence for more clarity on the descriptive statistical data.

***Table 1:*** *Quantitative Description o of Intercepted Plastic by River and Polymer*

| River Site | Total Mass (kg) | HDPE (%) | PET (%) | Mixed (%) | Observation Days |
|---|---|---|---|---|---|
| **Nile (Egypt)** | 987 | 15 | 68 | 17 | 122 |
| **Volta (Ghana)** | 712 | 19 | 61 | 20 | 120 |
| **Vaal (South Africa)** | 601 | 20 | 61 | 19 | 121 |
| **Total** | **2300** | **18** | **64** | **18** | **363** |

**Source:** *Authors' Own Construct, 2026*

## 4.2. Qualitative Findings and Analysis on Three Core Themes

Thematic analysis of focus group transcripts, ethnographic field notes and oral history narratives yielded three recurrent themes that fundame ntally challenge the technological determinism of existing plastic credit f rameworks.

### *Theme One (Dawn Ownership)*

Coded as dawn ownership, the first theme captures a deeply entrenched informal norm regarding property rights (Okwei et al., 2026). Within this norm, the first waste picker who arrives at a given riverbank stretch at daybreak acquires first claim to the plastic accumulated overnight, irrespective of fences, sensors, or downstream landowners. This heuristic is customary and socially cognisable. Comparative property law scholarship in Global South waste contexts identifies the resnullius regime, meaning 'ownerless thing', as the most efficient property arr angement for waste, where ownership is established by first possession under the 'first in time, first in right' principle (Danese, 2021). Dawn ownership therefore represents a living, functioning res nullius regime that predates and will outlast any blockchain deployment. This finding directly supports Ostrom's insistence that appropriation rules must emerge from community practice rather than technical architecture alone. To this effect, a credit system designed without accommodating this rule is a colonial imposition, one that repeats the historical pattern of displacing local institutional knowledge with external technical frameworks, a tendency that Ostrom's polycentric governance model explicitly warns against.

### *Theme Two (Floating Plastic Has No GPS)*

The second theme, encoded floating plastic, resolves border uncertainty without using GPS, where participants repeatedly stated that plastic in motion, drifting between riverbanks, crossing administrative boundaries, and becoming entangled in floating vegetation-defies spatial fixity. This is consistent with recent experimental work on common-pool resource governance, which reveals that ambiguity about resource boundaries dramatically weakens user cooperation (Tu et al. 2023). When administrative zones lack clear differentiation for resource users, institutional trust fractures, resulting in highly uncoordinated resource extraction. Current plastic fences regard the river as a static property boundary, as field survey participants demand that governance boundaries must follow seasonal flows, flood patterns, and drift trajectori es—variables which are best represented through oral histories rather than load cells.

### *Theme Three (middlemen erase our names)*

The third theme, middlemen erase our names, articulates credit invisibili ty. Across all three river sites, participants reported that intermediaries—specifically consolidators, buy-back centre operators and transport agent s—routinely remove identifying information from waste shipments before credits are issued, rendering the original collector invisible to the credit ledger. This finding is strikingly corroborated by a 2025 cross-bor der investigative study of plastic credits in Kenya, which uncovered that corporate-backed plastic credit projects bypass informal waste pickers almost entirely, with participants reporting no improvement in wages or consultation since project inception (Simpson et al., 2025). More broadly, a white paper published by the World Economic Forum in 2025, cited in Leal-Arcas, (2026), emphasised that circular supply chains cannot be built on invisible or exploited labour, and that elevating traceability in the informal waste sector is fundamentally a challenge of recognition and dignity, not only the technical integration. Middlemen erasing our names in this instance is not anecdotal but deemed systemic.

### 4.3. Thematic Discussion in Line With the Application of Ostrom's CPR Framework

Ostrom's design principles provide the diagnostic lens for translating these qualitative themes into engineering requirements. First, dawn o wnership demands that smart contracts recognise appropriation rules derived from community practice. The *res nullius* logic of 'first in time, first in right' cannot be overridden by sensor ownership. The blockchain should instead allocate provisional credit to the first registered picker within a GPS-defined river segment at sunrise, triggering dispute resolution protocols only in the event of competing claims.

Second, the floating plastic has no GPS and requires clearly defined boundaries to be dynamic rather than being simply static. Ostrom insists that boundaries must be collectively understood and mutually e nforceable. Our ethnographic mapping of drift corridors and seasonal flood zones is intended to feed directly into smart contract geofencing parameters that shift month by month, ensuring that governance follows plastic, not the contrary.

Eventually, the third theme coded, middlemen erase our names, is t he most direct violation of Ostrom's principles of effective monitoring and congruence, where those who appropriately (collect plastic) must also be the ones who benefit from provision (credit issuance). The solution is graduated sanctions whereby a first infraction by a consolida tor (failure to transmit collector identity) triggers a warning and temporary suspension of credit trading privileges; a second triggers a fine enforced by smart contract, while a third results in permanent exclusion f rom the verification oracle (Korol & Korol, 2024). Additionally, nested enterprises, stemming from Ostrom's principle that governance must operate from local to regional scales, point directly to the local waste picker cooperative as the first verifier. Before any credit reaches the blockchain, the cooperative validates that the named collector indeed performed the extraction, transforming the middleman from an invisibil ity machine into an auditable node.

### 4.4. Cross-country contrast (Case Analysis of Selected African Economies)

The three national contexts revealed markedly distinct institutional pref erences that defy a one-size-fits-all blockchain architecture. Egyptian informal pickers demanded daily cash settlement, reflecting a high-velocity, low-trust environment where payment delay is equated with payment denial. The study findings here support the findings of Malik (2023), who investigated the contemporary challenges and adaptive strategies used by informal waste recyclers in Manshiyat An-Nasr to secure their right to waste.

In contrast, Ghanaian participants expressed a strong preference for weekly collective credit distribution through their existing cooperative structures, prioritising group solidarity over individual immediacy, while South African waste pickers, many of whom are registered on the South African Waste Picker Registration System (SAWPRS), insisted on written ledger backups despite being presented with a fully functional blockchain interface, a pragmatic response to both digital literacy gaps and a history of opaque auditing in local recycling programmes.

These contrasts validate Ostrom's insistence on polycentric rather than uniform governance. In this instance, a single smart contract template cannot serve all three nations; instead, each must deploy a loca lly parameterised oracle. Thus, the field revelations indicate that Egyptian contracts have daily settlement triggers and Ghanaian contracts have cooperative multi-signature requirements, while South Africa opposes parallel off-chain ledger synchronization. The blockchain is not the rule-maker—the community is—but it re-enforces what the community has already decided. Table 2 below shows the descriptive statistical details regarding the individual country preferences.

***Table 2:*** *Cross Country Institutional Preferences*

| Preference | Egypt (Nile) | Ghana (Volta) | South Africa (Vaal) | Chi-Square p-value |
|---|---|---|---|---|
| Daily cash settlement | 92% (23/25) | 12% (3/25) | 24% (6/25) | $p < 0.001$ |
| Weekly collective credit | 8% (2/25) | 88% (22/25) | 16% (4/25) | $p < 0.001$ |
| Written ledger backup required | 16% (4/25) | 28% (7/25) | 88% (22/25) | $p < 0.001$ |

***Source:*** *Authors' Own Construct, 2026*

From the above, the chi-square test of independence applied to the cross-country preference data yielded a statistically significant association ($\chi^2$ (4) = 48.2, $p < 0.001$), compelling us to reject the assertion that inst itutional preferences are independent of national context. In practical terms, this result confirms that a waste picker's preferred settlement mechanism—whether daily cash, weekly collective credit, or a parallel written ledger—is not randomly distributed but is instead systematically predicted by the country in which they operate. Egyptian participants overwhelmingly favour daily cash settlement (92%), a pattern consistent with a high-velocity, low-trust informal economy where any delay is interpreted as a default. Ghanaian participants, by contrast, demonstrate a strong preference for weekly collective credit through cooperatives (88%), reflecting existing solidaristic norms and trust in group-based distribution. Among South African participants registered on the national waste picker platform, 88% require paper ledger backups to complement the blockchain, demonstrating a pragmatic hybridity arising from negative experiences with opaque digital systems. The chi-square result therefore validates Ostrom's principle of polycentric governance: a single, uniform smart contract would fail across these three settings because the institutional preferences are not interchangeable. Instead, the statistical evidence mandates that blockchain architectures be locally parameterised, with settlement frequency, group validation rules, and o ff-chain ledger requirements tailored to each riverine community's governing logic.

Ultimately, the integration of qualitative themes with Ostrom's CPR framework demonstrates that a plastic credit is not a mathematical token

but a social contract inscribed in code. The quantitative fence data captured 2.3 tonnes of plastic, but the qualitative findings captured something far more valuable: the institutional grammar of riverine commons governance. Without "dawn ownership", the system illegit imises first possession; without solving boundary ambiguity, it generates inter-community conflict; without curing credit invisibility, it reproduces the very exploitation it claims to remedy. Future studies need to apply this analysis to wet-season conditions and broader African river basins; however, the primary engineering rule is already evident: design the blockchain system from the riverbank upward, or abandon its construction entirely.

## 5. Conclusion

This study has demonstrated that a blockchain-verified plastic credit is legitimate only when riverine communities co-own the verification pr ocess, a finding that directly challenges the prevailing technological determinism of global plastic offset markets. Recent investigative work on plastic credits in Kenya has shown that corporate-backed projects ro utinely bypass informal waste pickers, delivering little evidence of promised benefits and actively undermining the livelihoods of those who actually retrieve plastic from rivers and landfills (Kain et al., 2022). The qualitative-first, Ostrom-grounded methodology confirms that sensor accuracy alone cannot generate trust; rather, trust emerges from polycentric governance where dawn ownership, boundary reciprocity, and credit visibility are encoded into smart contract logic alongside load cell data.

The study provides a twofold theoretical contribution: first, it applies Ostrom's Common-Pool Resource theory to digital tokenised commons, proving that a plastic credit is a social contract embedded in code rather than a detached financial instrument. Emerging research on blockchain and the digital commons confirms that Ostrom's design principles—pa rticularly clearly defined boundaries, collective-choice arrangements, and graduated sanctions—are directly translatable to smart contract architectures, provided that governance structures are intentionally designed to prevent unequal voting power and centralised control masquerading as decentralisation. Additionally, the study operationalises Ostrom's framework as a prescriptive engineering blueprint, moving

beyond descriptive commons analysis to machine-executable rule sets that evolve with community practice.

On the practical front, this study contributes to the open-source sma rt contract template for river fence projects, parameterised by qualitative themes such as shift handover rules, seasonal geofencing, and cooperative multi-signature requirements. Current work on plastic credit systems confirms that smart contracts can enforce automated compliance with extended producer responsibility (EPR) and environmental, social and governance (ESG) frameworks, but only when the underlying verif ication logic is co-designed with waste pickers and recyclers. Our template explicitly encodes dawn ownership as a conditional oracle, boundary ambiguity as dynamic geofencing, and credit invisibility as a graduated sanctions hierarchy.

The study acknowledges two principal limitations. The empirical deployment was confined to three river systems (Nile, Volta, and Vaal) over a four-month period, capturing only the dry season. Wet-season data—when flood pulses mobilise larger plastic loads and alter drift corridors—remain absent, and generalisability to other African river basins (e.g., Congo, Zambezi, and Niger) requires validation through extended, multi-season deployment across a broader range of hydrological regimes.

No blockchain can replace a fisherman's word—but it can amplify it. Engineering trust from the riverbank upward demonstrates that circular economy technologies must not seek to substitute local knowledge with cryptographic certainty; instead, they should utilise distributed ledgers to ensure such knowledge is legible, enforceable, and fairly compensated.

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