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# Drinking Water Quality Provenance Tracking for the Informal Water Market using Blockchain Technology

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**ABSTRACT**
The purpose of this article is to explore the application potential of blockchain technology to support quality provenance tracking system for the verification of informal water markets' product quality. Due to lack of traceability system in the informal water market, consumers lack trust in their products and end up investing heavily in quality improvement schemes at the expense of high cost both in the healthcare front and water environment's. A scoping review method from the existing blockchain provenance tracking literature is deployed. The result shows that blockchain technology is capable of hosting an informal water quality data tracking (provenance) system borrowing from the practice in supply chain sector according to (Tian, 2017).The article contributes to the possibility of expanding the application of the emerging technology; blockchain in the domestic water supply sector.
**Keywords:** blockchain, application, tracking and network

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## I. INTRODUCTION

Throughout human history, water supply planning has always assumed a stationary replenishing rainfall pattern. Unfortunately, because of the anthropogenic global warming impact on the global climate system, that assumption is dead according to Milly et al., 2008 [1]. As a result, many formal water markets' services (public water supplies or municipal water supply systems) are unable to meet the burgeoning demands, thereby giving a chance for the informal water markets to fill the widening demand gap.

This situation calls our attention to search urgently for a sustainable water security solution including the incorporation of the informal water market services. Currently, the informal water market uses vending methods; a practice mostly found in the developing world as per the synthesized literature by Sansom, 2004 [2] and Kjellén and McGranahan, 2006 [3]. This however, is at the expense of high costs to consumers .The consumers have a distrust on the informal water quality as observed by Haßler et al., 2018 [50].The use of informal water sources has occasionally caused disease incidences as reported by Singh et al.,2017[44] due to their contaminated nature as noted by Shields et al.,2015[45].

Already studies have shown that about 10,000 people die daily due to use of these unclean sources of water at the global level as observed by Sticker and Juchniewicz, 2009 [4]. In India alone, Hammond et al., 2009 [5] reported that about 780,000 die annually from diarrheal related diseases. Just as in food industry where consumers have become mindful of food quality, water provision requires a similar ethical considerations by suppliers as discussed by Sims,2011[46].Towards this aspiration water access was placed at the centre of Millennium Development Goals by the global community, but whose quality can be trusted like data in the computing world as Górski et al.,2005[48] had postulated. This can only happen if provenance tracking system is set up as elucidated by Tyler,2018[49].This is so particularly needed when groundwater is the alternative source of water for the informal market according to Haßler et al., 2018[50].But the latter's quality needs real time provenance tracking or monitoring as suggested by Yang et al, 2015[51] and most recently by Shivasharanappa and Prema (2018) [59].

### 1.1 Use of innovation in the quest for water security

The quest for a sustainable water security solution therefore demands the use of innovations through deployment of technology as advised by Briscoe, 2009 [6] and later by Chen and Chen,

2015[52]. Blockchain application is proposed here for the informal water market in line with the global developmental wishes as proposed by (Pisa, 2018[7] and Ahram et al., 2017 [53]. Little has been done to explore the application potential of blockchain technology in the informal water market which this article considers as the hub for informal water alternatives.

According to Hartigan,2009[8], the global trend shows that surface and groundwater in poor countries are increasingly becoming contaminated thereby scaling up the vulnerability of consumers to water borne diseases as per findings by Peletz et al.,2018 [54]. In Bangladesh for instance, Milton et al., 2012[42] and Anawar, 2012 [47] noted that the high exposure to arsenic poisoning from groundwater consumption was a big burden to many households. As a solution, recommendations on the use of rainwater harvesting as an alternative to reduce filtration cost as well as to provide them with a safe source of drinking water were made.

Similarly, in Nairobi city, the capital of Republic of Kenya in East Africa, a problem of high fluoride concentration was identified in a study by Coetsiers et ,2008 [56], but which offers a significant relief on water shortage to consumers during drought times. Many scholars like Richards et al.,1967[**55**] had suggested the monitoring of the fluoride concentration of Nairobi city's borehole water sources to avoid dental fluorosis disease as had been witnessed in the European children in the early 1950s as reported by Nevill,1953[57].

To counter these quality issues in the informal water market, blockchain technology provenance tracking system is proposed. Blockchain technology's potential lies in its customizable solutions according Lubin et al.,2018[9]. Recently, Emma in her 'blockchain for water' blog series argued that, blockchain is able to connect individuals, communities and society at large with immutable data quality for better planning towards a sustainable water security Emma,2018[58] reinforcing the earlier assertion by Richter,2009[10] on sustainable water use.

### 1.2 Blockchain technology basics

Blockchain is an innovation of information transfer that runs on the backbone of information communication technology as observed by Wrights and De Filippi, 2015[11] and Ahram et al., 2017[53]. It provides security according to Salman et al., 2018[12], anonymity and data integrity without a third party intermediation as reported by Yli-Huumo et al., 2016[13]. Blockchain will bring a shift from internet of information to internet of values. And Peters and Panayi,2015[14] add that blockchain is going to make transactions more instantaneous and less costly in the coming days.

Given the latent potential of blockchain technology in hosting a platform supporting water quality provenance track system, the authors here set out to demonstrate this capacity. In the end, it is expected that this may significantly contribute to improving water security in the developing world where informal water market plays a major role in augmenting water supply shortages especially during drought times. The rest of the article presents; related work, methods, results and conclusion.

## II. RELATED WORK

The problem of providing an adequately treated public water supply to the consumers in the developing nations has been discussed extensively by many scholars. In a study by Abiola,2010[30] conducted in Ibadan city, residents were found to be depending on groundwater whose lead and coliform contaminations were detrimental to their health. The study recommended for the expansion of the existing public water supply network to the teaming Ibadan's population.

Earlier, a review study by Gundy et al., 2004[31] had also established that drinking water in poor nations had microbial contaminants leading to high disease prevalence to which they proposed home based treatment and storage interventions. This latter solution had been suggested by Sobsey et al.,2003 [32] for both source and point of use water quality improvements using chlorination to reduce vulnerability of the populations to waterborne diseases. For East Africa major towns for example, a study by Thompson, 2000[33] had established that public water supply was in a declining trend between the year 1967 and 1997, and households were turning to water kiosks and vendors' supplementation as a coping method.

This situation has not changed, for instance, Ochungo et al., 2018[34] recently reported the case of Langata, a Nairobi city neighborhood, where households also rely on water vendors but at the expense of groundwater depletion threat. In some other instances, for drinking water, sachet water is also being touted as a solution according to the works by Stoler et al., 2012[35]. From the foregoing, the issue of informal water quality control is a case where blockchain application can potentially be tried using provenance tracking.

In the traceability, blockchain provenance has been used to offer a secure and immutable scientific data management as described by Ramachandran and Kantarcioglu,2017[15]. In the public information management, blockchain has found provenance tracking application in the

implementation of United Kingdom's General Data Protection Regulation Act, protecting residents' personal data at no fees as reported by Neisse et al.,2017[16].

This sort of governance application has also been reported by study Yermack,2017[17] in public record keeping since blockchain technology is immune to malware attacks according to Xu,2016[18]. In the food safety,Yiannas,2018[19] considers blockchain powered provenance tracking as a new era for food transparency, citing the case of Walmart business collaboration. The author argues that if the blockchain provenance tracking had been there in 2006, the source of spinach contamination which triggered the outbreak of the devastating E. Coli0157:H7 in US would have been solved faster.

It has also been used in healthcare record management revolution according to Mettler,2016[20] and in webjet travel industry using business-to- business concept where visitors are connected to hotel rooms as reported by Smith,2016[21]. Blockchain provenance has been applied in supply chain industry by IBM, the market leader of blockchain. Most payment platforms may soon be on blockchain tracking according to Peric et al., 2018[22] just as Greenspan,2018[23] highlights that blockchain provenance is adding real values on data sharing in; financial assets, identity management and supply chain coordination.

In terms of adoption, many sectors are venturing into blockchain. For example, in the property market, Graglia and Mellon,2018[24] proposed an adoption framework. The World Bank Group recently launched a blockchain lab to help track world's development challenges using decentralized data sharing as reported by Karacaoglu et al.,2018[25]. In the education sector, Fabian,2018[26] reports that UNICEF is extending its 70 years unmatched tinkering with new technology through blockchain tracking platform for real time data sharing of children in need of humanitarian help.

This trend of blockchain adoption has been highlighted in the study conducted by Pisa,2018[27] in which the author states that blockchain has the potential to address a variety of our social and economic issues. He cites the case of Inter-American Development Bank blockchain platform for asset registers and its use in refugee identity data among other areas. The issue of technology adoption has been studied for long. Many scholars have noted that technology adoption is a social process as reported by Mulgan,2006[28] and its successful diffusion requires that individuals sort of join maker movement as was asserted by Doughetty,2012[29].

For this reason,Yiannas,2018[19] advises on identifying a business case in a problem, identifying collaborators, developing proof of concept and conducting a case experimentation. This seems to suggest the idea of learning by doing as anchored in the initial technology acceptance models in literature. Given that informal water market is already a distributed network without a central control, blockchain enabled provenance fits perfectly to help in data sharing . The data to be shared is source water quality, the vendor operator information, the consumer information, consumption data and climate information to allow early warning preparedness planning.

From the adoption steps articulated by (Greenspan,2018), it is the argument in this article that, blockchain application in informal water market is possible, starting with; proof of concepts, encouraging collaboration between water sector actors and subsequently moving to a case study. This is likely to make water supply security both affordable and reliable in multiple dimensions. The rest of the article contains;

## III. METHOD

The authors of this article have used a scoping review method to sketch out the potential of blockchain in the informal water market by conducting a literature search within the internet. From the literature analysis, the meaning of blockchain technology is explained, its data management capability together with examples on blockchain provenance to showcase its potential application in water sector. Regarding the determinants for adoption, the article highlights the leading factors to influence its diffusion.

## IV. RESULTS

Conceptually a blockchain provenance tracking of informal water quality requires a systematic framing. It starts with the definition of the technology itself. In a basic sense, blockchain is a distributed database entity with a sequenced chain of blocks, with each block storying information of network activity as new blocks are added to the chain according to Risius and Spohrer, 2017[36]. Every piece of information in the blockchain remains accessible to authorized network constituents who in turn can add data to it through a verifiable transaction in the system.

Once the data is accepted consensually by majority vote, it remains permanently immutable according to Elsden et al., 2018[37]. The data history of the network is visibly to all nodes thereby eliminating the role of a centralized trust authority. Trust is achieved through a 'mining process' which guarantees the data fidelity and validity as reported by Tumasjan and Beutel,

2018[38]. On retrieval, a similar confirmation by network nodes ensues. In the end a new block is created by an algorithm according to Abeyratne and Monfared,2016[39]. The verification process before acceptance in the registry significantly fortifies the transparency, trust and tracking in the system.

For the provenance system to be functional a smart contracting system must be created as Kim and Laskowski [43] suggests. The smart contract system depends on a computer protocol or program running the blockchain platform. The program's basic architectural configuration is such that; it has a layer for program code and a layer for storage of files. Any authorized user in the network creates a contract by initiating a transaction event. It begins with creation of a protocol code of a contract which remains immutable according to a study by Delmolino et al., 2016[40]. So we have the user interaction face, the message relay framework, contracts storage and mining blocks. The storage file of the smart contract is kept in a block and the program logic is executed by agreeing nodes to allow adjustments in the blockchain as per figure 1 below;

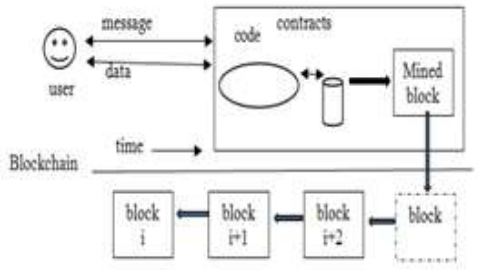


**Figure 1:** Conceptual framework of a blockchain

The proposed blockchain provenance tracking has 4 layers; the overall system, registration, protection and authority organizations. The decentralized distributed system which uses a blockchain based database to store and manage relevant data of the informal water market is proposed. As usual, there are different actors in this market typically comprising of; borehole operators, water tanker operators, water vendors of other categories, water agencies tasked with different roles of authorization (Certifiers) and consumer organizations at the community level. Each of these actors can add, update and check the information on vendor water quality in the database as long as he / she is a legitimately registered user in the system. Each water source will be assigned a unique code with a digital cryptographic identifier that links the physical source with its virtual identity in the system, like the physical and chemical attributes information profile of the individual water source. Similarly, users in the system are assigned their digital profiles, which amongst others, include; introduction, location, certification and relationship with the water source. The whole suite of data is kept in a blockchain ledger accessible to permissioned users. The system has governing rules which outlines interaction with the system by users and data sharing protocols.

With regards to registration, data updating and adding, an interested member is free to register through a system registrar. Such a member is provided with credentials and unique identifier codes with a pair of cryptographic key; public and private. The public key is to identifier the user within the system and the private key is to authenticate user interaction with the system for digital participation in all transactions. In the informal water market, a consumer receiving a delivery adds a new data into the water supply profile with his / her private key. When the borehole operator transfers water delivery to the vendor, both of them sign a digital contract to authenticate the exchange. This transaction data is added to the database and the system updates itself automatically.

When it comes to data security and fidelity or protection, the system allows users to provide the defining attributes and status to all consumers. For secrecy of private sensitive information, the system embedded protection will conceal such layered information from other parties while still transferring authorized data. For example, the consumers can sign a digital contract with dealers or vendors from upstream while keeping their identity private. On the role of certifying agencies, each organization inspectors are able to monitor operations with aim to enforce compliance with relevant standards to allow them update the profile of the actors. All the verification data are published in the system to enhance transparency of the informal water market product's quality.

When it comes to proof of concept application scenarios, it is important to first understand the linkages between members; borehole operators, delivery operators, community storage and authority organizations as shown in figure 2 below. The linkages shown between users are to match their unique identities so that one digital profile of the system is established.

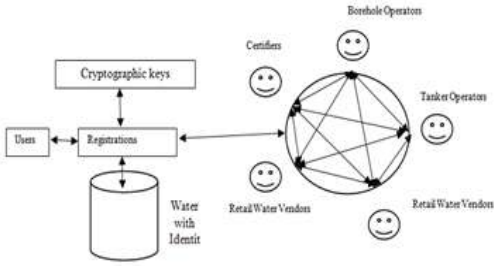


**Figure 2:** Conceptual framework of the provenance system

For the borehole linkage, the commissioned borehole water quality information; physical, chemical and microbial are entered into the system on borehole operator profile which is trackable by the other users within the wireless network running blockchain database. The same is repeated for the delivery operators; vendors and tankers. For the community linkage, the system is expected to shift from the existing hydraulic network where water utility company has direct connection with customers to one where, there is a community central storage.

The storage is at two levels; one for underground reservoir and the other is elevated tank for direct gravity delivery into user tap. This will retire all existing lot level pumping as well as lot level storage. Secondly, the consumer linkage with the community management unit is through smart meter system which is able to automatically update consumer water use information for billing and also for future planning. The authority linkage will allow for close monitoring by responsible agencies on the standard compliance and updating of the committed user profiles to weed out fraudulent players.

## V. CONCLUSIONS

This article has explored the potential of blockchain technology application in the informal water market through quality provenance tracking following from the food supply chain example as presented by Tian,2017[41]. It argues strongly for the adoption of blockchain provenance of the informal water alternatives as it allows verification of the important water quality for human consumption.

The lack of trust in the quality of such water has made consumers spend heavily on quality improvement schemes at the expense of other welfare needs. Besides, the uncontrolled nature of the informal water market in poor nations may lead to ground water depletion which may irreversibly impair their natural ecology. For sustainable water security solution, blockchain application in water sector will allow for real time data sharing to give room for adjustments in consumer behavior during times of water shortage.

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