

Aquatic ecosystem overthrow in the developing Addis Ababa due to concrete batch plant discharges

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Abstract: Concrete would be the most utilized material by humans, with global annual use of 25×10^{12} – 30×10^{12} kilograms. The fast-developing Addis Ababa consumes quite a high volume of concrete produced either from stationary or mobile mixers, with a vivid and undesirable consequence on aquatic and terrestrial ecosystems. However, no such study has ever been conducted to bring it to the attention of the relevant stakeholders and the scientific community. The objective of the current study was to shed light on the aquatic ecosystem impacts of concrete batch plants in Ethiopia. A quantitative and qualitative evaluation of such plants was performed using a cross-sectional design and basing it on a lifecycle and inventory study; regulation review, field data collection and analysis, and a survey of the public and institutional representatives were performed. The batch plants are located typically in three sub-cities of Addis Ababa, and most were commissioned during the years 2020 and 2022. A snapshot of the chemical analysis of water samples from the streams located adjacent to these concrete-producing plants indicated a pH of 11.4 ± 1 , total chemical oxygen demand of 10700 ± 870 mg/l, SO_4^{2-} of 1325 ± 60 mg/l, and NO_3^- of 17.5 ± 0.2 mg/l, which was found. The adjacent rivers are dried up. In fact, the regulatory and permit issuances to those particular plants are ineffective, worsening the environmental impact.

Key words: Aquatic; concrete batch plants; construction; environmental impact; river; streams.

1. INTRODUCTION

Basically, our lives and livelihoods are directly or indirectly dependent on the natural and engineered environmental systems whereby healthy urban streams and ecosystems are vital to cities with provisions ranging from water to food and air temperature regulation (Pandey and Ghosh 2023; Ranta et al. 2021; Raquel Calapez et al. 2023). Likewise, urbanization and population growth demand accelerated development accompanied by massive consumer production. Unfortunately, the urban and industrial development activities are posing threats to the rivers and terrestrial ecosystems on a local and regional scale if an environmental management system standard is not observed (Malmqvist and Rundle 2002). In spite of their huge positive implications, the rapid development activities and urbanization are abstracting the natural water on one side as raw material and are polluting back on the other side with resulting wastewater discharges, signaling the unsustainability of not only the water bodies but also of other socioeconomic developments (McMichael 2000; Srinivasan et al. 2003). In order to ensure urban ecosystem sustainability, therefore, the anthropogenic effects on natural systems such as the urban rivers have to be minimized, and if possible, be avoided. For developing and fast-urbanizing sub-Saharan countries like Ethiopia, timely reconciling of the socioeconomic development activities with nature, such as through avoiding water pollution in an integrated as well as adaptive approach, appears demanding.

The centers of productivity, the natural water bodies that contribute to temperature regulation, water and food supply, the sites for the urbanites' recreation, and more-the rivers, became open channels for wastewater flows and other kinds of waste dumping in Ethiopia's capital, Addis Ababa (Tibebu et al. 2022). This wastewater is partly coming from industries that are unfairly commissioned along riverbanks and are poorly regulated, already became seriously concerning. Locally, a significant proportion (80-85%) of these industries are concentrated in and around Addis

Ababa, accounting for over 65% of the total national, that are discharging their process wastewater without proper treatment into adjacent streams or rivers (Yohannes and Elias 2017).

A sector among those polluters is the construction industry. The huge expansion of the construction activities in Ethiopia, mainly concentrated in the capital, is heavily demanding for concrete supplies, which consequently triggered the boom in Concrete Batch Plants (CBPs) among other construction materials suppliers. Concrete is a type of construction material in which cement, aggregate, and admixture materials are mixed (Kim et al. 2016), and in fact it is the second most consumed material after water in the world (Gagg 2014). CBPs by process are connections of mechanical parts that are either mobile or fixed in a given area and are designed to weigh water, cement, aggregates, and admixtures and introduce the ingredients into the mixer for producing a batch of concrete (Deligiannis and Manesis 2008). Though concrete batching can be performed using either mobile or stationary mixers, this particular study focuses on the stationary CBPs in Addis Ababa, Ethiopia.

In its whole life cycle, concrete production has had environmental issues that include the generation of greenhouse gases, increased surface runoff following sand mining, urban heat islands, and potential public health implications from toxic ingredients (Miller and Moore 2020). These plants are mostly located adjacent to river passages, thereby abstracting their water demand and dumping concrete residues, wash discharges, and mixed wastewaters back to the rivers (demissew 2020). Such expansion of CBPs is defeating aquatic ecosystems in the capital, thereby resulting in the destruction of the aquatic biodiversity in addition to their visible particulate air pollution (Cooke et al. 2020). In spite of the rapid urbanization of Ethiopia and the booming of the construction industry, there is no such local study reporting on the environmental and public health impact (EPI) of concrete production in general and the CBPs in particular.

In this regard, both the industrial practice and the context of the enabling environment are unclear. Research questions such as 1) Are the CBPs in the city properly recorded, commissioned, and monitored or regulated? 2) How are the byproducts and wastes from the CBPs impacting rivers nearby? and 3) What are the views of nearby residents and the mandated institutions? Thus, the current study aimed to explore the aquatic environmental health impacts of CBPs with emphasis on streams in Addis Ababa using a mix of methods.

2. METHODOLOGY

2.1 Concrete material description

Though concrete is not the only material of construction, it is the most consumed material after water (Gagg 2014). According to People's Daily Online news, so far the largest concrete pour in a single project took place decades back during the construction of the Three Gorge Dam of China, consuming $28 \times 10^6 \text{ m}^3$, followed by an earlier construction of the Itaipu hydropower station of Brazil that consumed an annual concrete pouring volume of $3.2 \times 10^6 \text{ m}^3$ (PDO 2001).

Ethiopia is among the least urbanized but fast-urbanizing countries in the world, signaling the potential expansion of infrastructure whereby construction projects that consume concrete are at stake (Ozlu et al. 2015). Urbanization brings both opportunities and challenges, especially those related to sustainable development through wise consumption of resources and environmental protection. Indeed, by 2050, 68% of the world's population will live in urban areas, and 90% of such growth will be contributed by Asia and Africa (Terfa et al. 2019).

Addis Ababa, a fast-urbanizing city in Ethiopia, currently undergoes two kinds of transformations: an outward expansion and inner-city renovation with, in fact, attention being given to rivers' restoration within the inner city.

As fast urbanization brought construction of the high-rise buildings for residences like those condominium houses and apartments, commercial centers, public and private institutions, and

roads, as well as bridges and related structures, the massive consumption of concrete is inevitable. However, such consumption of concrete is resulting in public and environmental issues. From cement production, stone crushing, sand mining to water abstraction, the concrete industry poses environmental impacts that include air pollution, water pollution, and increased runoffs (Babor et al. 2009).

In order to enjoy the full health, productivity, religious, and socio-economic potentials of water bodies, including the urban rivers, countries, regions and international bodies have developed frameworks, policies, and strategies that consider rivers protection from pollution and restoration (Savenije and Van der Zaag 2000; Speed et al. 2016; UN Environment 2017; Wiering and Arts 2006). In this regard, Ethiopia made some effort to restore urban rivers, at least in selected cities like Addis Ababa and Jimma (Awoke et al. 2016). Unfortunately, in the absence of strong legal and institutional frameworks for urban river protections, urbanization will have a serious impact on the ecological integrity of the rivers and hence affect urbanites as a consequence of pollution against benefitting from the privileges of healthy urban rivers (Beyene et al. 2009). Thus, studies that focus on inter-sectoral issues that include construction, trade, and the environment will have great contributions in influencing policies and contributing scientific information to stakeholders for their subsequent intervention as well as filling existing knowledge gaps.

Furthermore, the abiotic environment is always interacting with the biotic environment, serving as a source and sink for various substances, whereby its proper management is mandatory, not just to enjoy the full resources but also to ensure sustainability in interactions (Group 2006; Lemly 1997; Wangai et al. 2016). Such a physicochemical environment includes the aquatic environs where one of the most required needs of humans, perhaps next to air/oxygen, is met-water. Such aquatic systems include rivers that are in continuous interaction with hydro-geochemical cycles so as to keep a healthy and productive ecosystem (Mondal and Patel 2022). When it comes to urban settings, the importance of rivers is beyond the provision of ecosystem services such that recreational, transport, and other socioeconomic benefits are few to mention (Leal Filho et al. 2020; Lundy and Wade 2011; Ma et al. 2022). However, such ecosystems are under pressure following urbanization, industrialization, and rapid population growth (Xiu et al. 2022), especially in developing countries like Ethiopia (Koroso et al. 2021; Yohannes and Elias 2017).

Such ecosystem services provisions are indispensable to social development (Xiu et al. 2022). Traditionally, river health is measured using some physical, chemical, and biological characteristics that are assumed to be healthy for the ecosystem's functioning and the protection of public health. For instance, the amount or concentration of the dissolved oxygen (DO) can be a good indicator. A study by Liu and Liu (Liu and Liu 2009) describes a healthy river in the context of its social and ecosystem services, whereby the social and natural functions of a river have to perform in balance. While quality is a subjective and generic term, an abundant and clean flow of rivers is suggested as a key parameter to river health, as the environmental flows are very important to safeguard the river's health (Karr 1999). In fact, rivers and cities or urban settings are historic, and their interaction is established (Phong 2015).

2.2 Study area

Addis Ababa has an altitude ranging from 3000 m above sea level around Entoto Mountain down to 2100 m above sea level around Akaki. This fast-urbanizing city is incomparably the largest in the nation. Addis Ababa is playing the political and economic role of the country, with almost over 65% of the industries in the country concentrated in and around it, while it is undergoing huge vertical and horizontal expansion. Currently, it is renovating massively, whereby high-rise building constructions are vivid everywhere. The context of the urban environment is concerning, as the rapid population growth and urbanization of Addis Ababa have been putting tremendous pressures on the city's physical and biotic environment. River, soil, air, and water pollution as a result of industrial wastes and even domestic wastes are becoming a growing concern.

2.3 Study design, method and sampling

The current study has applied a cross-sectional design whereby it has been conducted within two seasons of a year.

A mix of methods was applied to understand the environmental pressure mainly by CBPs on the urban streams, the quantitative context of CBPs, mandate and institutional circumstances, as well as that of concrete consumption. Based on initial observation and preliminary information, areas in Bole, Yeka, and Akaki Kaliti sub-cities were identified for investigating aquatic ecosystem impacts of CBPs in Addis Ababa, Ethiopia.

Regarding sampling, upon refined information regarding CBP's installations in the city, Bole sub-city was selected as the area of focus. Bole sub city is one of the eleven sub cities that is expansive and is a place where huge urban infrastructure is located, including Bole International Airport, and is perhaps the most developed area of the city. Of those districts under Bole sub-city, district 12 is relatively peripheral and is still expanding as it is not bounded spatially like other sub-cities, and most of the city's CBPs are located in this particular district.

There are numerous CBPs adjacent to the tributary streams of the Akaki River. Most of the processing plants are functional at present. Within those CBPs in the Bole district, two located on both sides of a seasonal stream flowing through the Bole International Airport catchment down to the Akaki River were identified. The water sampling strategy is also presented (Table 1). In order to account for the effects of the CBP, triplicate samples of water were collected at different locations of the stream, which are above stream, midstream, and downstream points. Further, residents around those plants were also interviewed systematically to get key information on the quality history and functionality trend of the streams.

Table 1. Sampling sites (US: Up Stream, DS: Down Stream, CBP1,2: Concrete batch plants 1 and 2 that face each other and the stream being in between)

Sites	Designation	Remarks
1	US (appx.100 m above CBP1,2)	Control
2	CBPs 1,2	Effluent effect
3	DS (appx.200 m below CBP1,2)	Dilution effect

At the CBP's sampling point (at Site 2), process effluent and concrete wash wastewater are discharged directly to the stream. There were two additional sampling points arranged upward of the stream, namely Site 1 (UP: the upstream sampling site was located at an estimated distance of 100 m above the effluent entering point) and Site 3 (DS: the downstream sampling site was located some 200 m after the effluent entry point). Schematic representations of sampling sites are depicted (Figure 1).

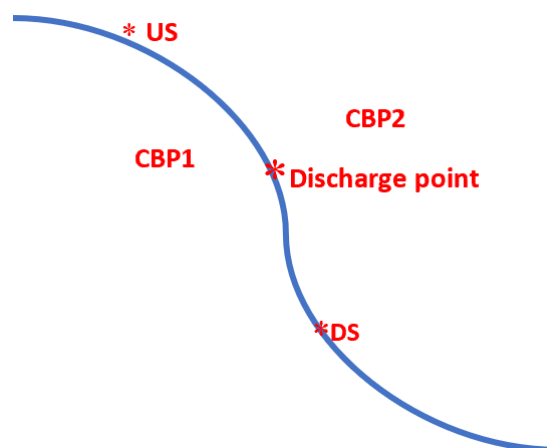


Figure 1. The water sampling points of the adjacent stream.

2.4 Data collection

2.4.1 Secondary data sources

Fundamentally, construction input manufacturers' data that include CBPs were searched from different stakeholders using official letter communications and visiting websites. To this matter, several publicly mandated sectors, such as the Customs Authority of Ethiopia, the Ministry of Trade and Industry of the country, sub-city Administrations, and personnel, were contacted to gain access to relevant information. Fortunately, a list of them and their attributes was collected from the Addis Ababa Environmental Protection Authority (AAEPA).

Scientific and technical reports were also accessed through various means, such as through formal letter communications, and were reviewed for possible synthesis on the state of the art in concrete production and its lifecycle, consumption, and their associated environmental concerns from a global to local scale.

2.4.2 Key informant interview

Six key informants were selected using purposive sampling techniques in order to gather detailed information through face-to-face interviews. The criteria of selection for informants were largely based on their closeness to CBPs. Interviews were taken place using questions prepared beforehand, which were crucial to the objective of the study and to support the information gained through the observation.

2.4.3 Observational checklist

Before site visits, observation checklists were prepared that contain relevant points with regard to CBPs in order to observe the different environmental characteristics of the study area. In this regard, the urban rivers adjacent to CBPs were observed ideally sectioning the upstream, midstream, and downstream contexts. The soil and other topographic context were also observed. In fact, the CBP's batching operation that included the input materials and chemicals was also included.

2.4.4 Physicochemical water sample analysis

Triplicate water/wastewater samples were collected within two weeks from the three sampling points as indicated in figure one. All the water samples were collected using clean polyethylene plastic bottles, which were labeled on-site appropriately. The samples were stored in an icebox and transported to the AAEPA laboratory for analysis. Selected physicochemical parameters were analyzed according to accepted standard methods within the premises of the AAEPA laboratory that are comparable to other international standards (APHA; WWA & WEF 1999). The pH was tested using the electrometric method, which was determined using a glass electrode and a reference electrode according to the USEPA-NERL: 150.1 (LaSota et al.). Sulfate was analyzed using the Sulfaver 4 method, which was also accepted by USEPA for a specified concentration range (Hatch Method 8051) and using DR/2010 (Mbui et al. 2016). The nitrate concentration was determined using spectrophotometry in a cadmium reduction method (Cortas and Wakid 1990). This colorimetric method involves the contact of nitrate in the sample with cadmium, which will then form a red color in steps, and the color is later measured at a wavelength of 543 nm using a DR/2000 instrument. The total chemical oxygen demand (COD) was determined using the USEPA Reactor Digestion Method (Xia et al. 2018).

2.5 Data analysis

The questionnaire and the checklist were cleaned and tested before data were collected.

Experimental data were also obtained from AAEPa lab premise. Data were then entered into spreadsheet and mostly presented in a descriptive statistics approach.

3. RESULTS AND DISCUSSION

3.1 Concrete production in Addis Ababa city: profile, environmental hygiene and mandate contexts

CBPs appear environmentally critical and also demand consideration for their wider public health impacts. The sites of production evidenced solid piles of concrete waste that were thrown into adjacent streams and did block them, and grey wastewater is forming large pool down the slope of the site. The issue of concern with this particular construction input supplier begins with the issuance of the permit in the country or city. Though technically appearing relevant, the offer of work permits to commission the CBPs in the capital of Ethiopia is not solely performed by the AAEPa. Permits are issued by different institutions at different levels, from federal to local, which may have a stake in the construction, trade, and industry sectors. Though issuing permits and regulating pollution limits is environmentally critical, the mandate for permits is very much diffused (Novotny 2002). In the interest of uncovering the local context of large-scale and static batch concrete production in the city, the current study managed to acquire quantitative information on such process plant profiles where their permit is offered (Chen et al. 2019; Jahiel 1998) by the AAEPa, and therefore results may not be exhaustive. Interestingly, the acquired quantitative information is broader in scope in the context of construction works, as it ranges from quarry sites to installation of batch concrete and asphalt-making plants.

According to AAEPa, there are around 470 construction input suppliers, including those batch concrete makers in and around the city since 2008. Indeed, some of them got their permits revoked, mainly due to the maturity of the period, as it has to be renewed. The construction input suppliers are categorized based on their product or service into white stone, black stone, crushers, sand, filler gravels, and the batching plants. The quarry sites for these suppliers' range between one and 600 m² by occupancy, and all are exclusively private entities. Based on the data accessed, it appears that the distribution of CBPs in the capital appears to be unequal, most being concentrated mainly in two sub-cities; Bole and Akaki Kaliti. This might be associated with the nearness to raw materials, the availability of land area, and the relative intensity of constructions activities undergoing (Table 2). In fact, these two and Lemi Kura sub cities are not confined territorially and have better access to minerals and land.

Table 2. Lists concrete batch and asphalt plants and their location in Addis Ababa

CBPs	Sub city	District	Year established	Shape area (m²)
CBP1	Akaki	11	2020	37948
CBP2	Bole	12	2020	10394
CBP3	Akaki	9	2022	26820
CBP4	Bole	12	2022	19502
CBP5	Bole	13	2020	16849
CBP6 (asphalt plant)	Bole	12	2022	28820
CBP7	Bole	12	2022	30646
CBP8	Lemi Kura	14	2022	14271

The installations of CBPs in the city are dated typically between 2020 and 2022, which is recent, and the expansion of such emerging plants follows the construction boom. From table two it can be noted that, including the asphalt plant, the majority of the batch plants are located within district 12 of Bole sub-city where the current study has focused on delving into the environmental and public health implications with them, mainly focusing on urban stream pollution.

Table 2 also indicated that there exists a total of 9 CBPs built within three sub-cities of Addis Ababa, occupying an area of 185248.8 m². This booming of large-scale CBPs is unprecedented even in the country, demanding attention on the determination of its contexts in view of its public and environmental health, whereby the issue of sustainability may ultimately be at stake. In this regard, a holistic overview of concrete mass production from the quarry to construction sites is necessary, and that will be addressed in the life cycle section. The locations of those particular CBPs in a district within Bole sub-city are indicated in figure two with a red line. As it can be seen from the figure, the industries are concentrated in a certain corner of the city (Figure 2).

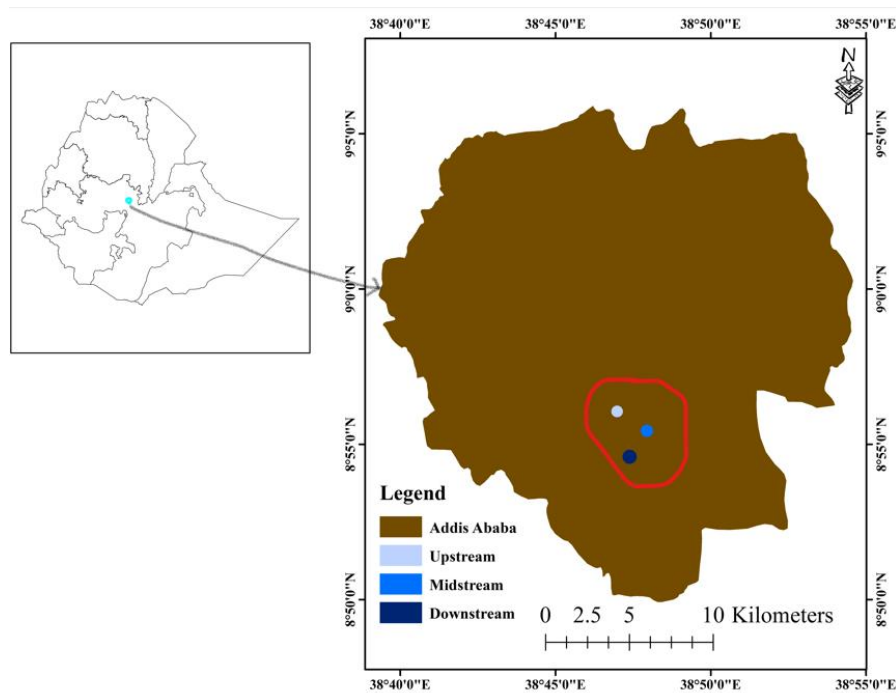


Figure 2. Map showing the area where the studies CBPs are located and water samples were collected (made using ArcGIS tool).

It is unfortunate that most of the CBPs are located adjacent to seasonal and year-round streams. In fact, a passerby can just feel the extent of cement-mud run over by concrete-carrying trucks, the pile of concrete debris on river ways, all associated with the towers of CBPs. The detail of the environmental context of such plants is addressed in the section where checklist-based elucidation is depicted.

Thus, given the fact that the number of CBPs swiftly rose in just a couple of years and there is diffused responsibility by the regulatory or competent authority, the operational conditions of those plants need urgent attention. If left as it is, the greying and cementation of the urban streams where CBPs are adjacently located will not only be inevitable but also already become visible. These and the inner city's streams wherein domestic wastes are channeled will make the city bad for living in. As a matter of fact, there lacks a clear policy regarding wastewater management that does agree with the city's development policy. Indeed, lacking such environmental and public health conscious monitoring will undoubtedly result in failure to achieve the sustainable development goals that push for sound water and wastewater management and the lifecycle approach as stipulated by the United Nations (Sachs et al. 2019).

3.2 Life cycle perspective on concrete production and its environmental footprint

At first, it is difficult to say its life cycle since it is obvious that the produced concrete does not return to either its parent component or rejoin the plants for reproduction, thereby closing the loop.

Rather, the fate of the produced concrete is either being a building or being dumped somewhere after demolition. However, such analyses of input-output conditions in concrete production are important for process improvements, thereby explaining the environmental impacts of such processes.

As a composite material of construction, concrete production in batch plants involves the use of water, cement, sand, gravel, and additives for a batch of product. The aggregates, the belt conveyor, and the hoppers for the raw materials are depicted in figure five, which is a photograph taken during the field study on one of the CBPs in Addis Ababa. In the case of Addis Ababa, these raw materials are delivered by tracks, and after the processes, specialized ready-mix concrete trucks deliver the mix to construction sites (Figure 3).



Figure 3. A typical stationary concrete batch plant located in Addis Ababa.

Past studies indicated that concrete batching plants are normally located around a city to reduce transportation time, and the average CO₂ emission due to batching is estimated at 0.0033 t CO₂-e/m³ of concrete produced (Flower and Sanjayan 2007). Of those models for life cycle assessment (LCA), including the one based on standard ISO 14044/2006, the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model is common, and its derivation or extension is reported for concrete production LCA studies, such as in the United States by Hottle and colleagues, which was published in 2022 (Hottle et al. 2022).

Indeed, in realizing cleaner production systems, studying the lifecycle of products has helped indicate where to intervene so as to reduce environmental footprint while maintaining the desired quality of the product. This has become more interesting recently due to the need for an environmentally sustainable design. In this regard, studies have already determined the contribution of different processes and inputs for a portland cement-bound concrete production where the aggregate emission ranged from 0.29 to 0.32 t CO₂-e/m³ (Flower and Sanjayan 2007). Several studies have also identified environmental impacts related to concrete production, of which particulate matter, as well as metals, dioxins, and furans resulting from fuel combustion, are associated. In terms of water footprint, around 10% of the world's industrial water withdrawal is due to concrete production (Hottle et al. 2022).

Thus, based on literature (Bhutange et al. 2021; Chandel and Gautam 2020; Faleschini and Pellegrino 2014) it has already been determined that the following consumptions are applied per ton of concrete production:

- 143.94 kg to 150.73 kg of portland cement
- 89.90 to 101.85 liters of water

- Additive (Super-plasticizer for concrete that is considered as 1.5% of the amount of cement
- 14 kWh of electricity

Within the circular economy perspective, recycling of the construction and demolition wastes does not only reduce the extraction of the virgin raw natural materials and reduce waste generation and disposal, but also it shows huge energy savings. In fact, around 60% of the environmental impact of concrete production comes from the cement production in a cradle-to-grave scenario. Such a reuse scenario has brought a significant reduction in freshwater ecotoxicity (63%) and water consumption reduction by 17%. Therefore, replacing raw materials, reusing the same wasted material, changing process efficiency, and having a dedicated policy as well as legislation appeared crucial for reducing the impacts of concrete batch production based on LCAs (Cerchione et al. 2023).

3.3 Physicochemical characteristics of the concrete production wastewater

Wastewater samples were collected during the study to have an insight into the physicochemical nature of the concrete production wastewater, which is just released into the gorges of the stream, where lastly it accumulates downslope, forming a pool of the visually grey and grease-containing concrete wastewater. Table 3 presents the results of the quality analysis conducted within the premises of the AAEP. From the table it appears quite clear that the pH (11.4 ± 1), the total chemical oxygen demand (10700 ± 870), SO_4^{2-} (1325 ± 60), and NO_3^{2-} (17.5 ± 0.2) concentrations measured in mg/l were incomparably high in mid-streams where the plants are located.

Table 3. Concrete production wastewater laboratory test results in different stream locations

Parameters	Unit	Sampling locations		
		Upstream	Midstream	Downstream
pH	-	7.35±(0.3)	11.4±(1)	11.06±(0.3)
Sulphate (SO_4^{2-})	mg/l	4±(0.2)	1325±(60)	300±(40)
Nitrate (NO_3^{2-})	mg/l	1.3±(0.02)	17.5±(0.2)	14±(2)
Chemical oxygen demand (COD)	mg/l	7±(0.2)	10700±(870)	30±(0.8)

As a matter of fact, the physical and chemical nature of concretes emanates from the characteristics of the inputs from which a batch of concrete is synthesized. That goes even back to the quarry sites property, where excavating and crushing of stones, scraping the sands downstream, and usually by the portland cement production. The pH of concrete wastewater is highly alkaline, whereby $\text{Ca}(\text{OH})_2$ is formed following the hydration of cement-mortar, a plastering composite (Mori et al. 1992; Wang et al. 2020). pH changes in water bodies obviously bring changes in aquatic chemistry and the associated problems (Stumm and Morgan 2012). For instance, an increase in pH can result in the mobilization of metals' species in rivers and streams while altering their bioavailability and toxicity potentials (Foldvik et al. 2022). In fact, such a phenomenon is associated with the death of living things in rivers that include fish. Indeed, for a normal aquatic functioning of rivers and streams, the desired pH ranges between 6.5 and 8.5 (Scholz et al. 2011). Based on the result of this study, the upstream pH falls within the normal range.

The sulfate and nitrate concentration increase can also be associated with some organic pollution as well as inorganic ones. Unfortunately, such pollution of urban streams is compounded by the lack of connections to municipal services, resulting in unsafe water supply, sanitation, and hygiene conditions. Since CBPs are located adjacent to urban streams and underdeveloped areas of the city, they are not covered with municipal services. The employees in those plants, as well as visitors, may dispose of waste and perhaps excrete in the open field and in those stream gorges. Further, due to the blockage of the urban stream courses by concrete debris, the velocity of the stream flow and its surface are significantly diminished, resulting in poor dilution capacity.

3.4 Checklists-based site survey of the concrete batch plants

A glimpse at the current status of CBPs, especially those located within the Bole sub-city of the capital, has been conducted voluntarily and with pictorial evidence. The checklist includes variables of concern such as identifying problems related to site selection for those CBPs, noting the extent of destruction of the urban streams, and the public health concerns basing on expert views. The impression of the current batching practice is undoubtedly undesirable from an eco-centric perspective, as can be seen from clearly negatively impacted adjacent streams (Figures 4 & 5). Indeed, sustainability is a concern in terms of the deterioration of the environmental resources that include water and sand for the same industry as well as other unrelated uses. The fact of the matter is that the leftover concrete, defective batch products, ready-mix concrete delivery tracks as well as mixing and batching vat washing wastewater are simply discharged into the stream, resulting in the cementation of the stream from its bed. Such cement conquest resulted in gray-dying of the streams, where part of the natural hydrologic cycle is even possibly interrupted, and also exacerbated evaporation of the water as the surface area of the stream bed is artificially extended due to such dumping. Indeed, it has already been reported that concrete is among the most damaging materials made by humans (Cooke et al. 2020).



Figure 4. A photographic view of one of the streams encroached by CBPs and its volume of water and color from upper side (left) and the pool of concrete wastewater down stream of it (right).

The public and environmental concerns do not end there; concrete batching also releases chemicals with the wastewaters. Even though $< 5\%$ by composition, admixture compositions that include accelerators, plasticizers and retarders constitute some of the eco-sensitive chemicals such as calcium chloride, calcium nitrate, sodium nitrate, pigments, lignosulfonate, and sodium gluconate. Hence, the release of such constituents into waterways will not be without damage. It has already been reported that concrete can interfere with the biogeochemical processes that occur in aquatic environments (Cooke et al. 2020).

Within an estimated length equivalent to a football field, three CBPs are located within district 12 of Bole sub-city of the capital that are owned by different companies where the occupancy time of the plants is different but very briefly in a span of two years. The two are just situated on each side of one of the rivers where the earliest one is located distances away and adjacent to the other stream. Such a series of establishments within a short distance in two years' time where two to three, largely seasonal, rivers flow does not just tell of the demand for concrete to support the booming construction industry, but it also informs about the need to pay attention, as early as possible, to the undesirable public and environmental consequences therein. Given the poor

practices of post-project realization environmental impact monitoring practices in the developing world, including Ethiopia, the graying of blue and green ecosystems is inevitable. Such local acts may not only bring local problems as the effect touches one of the global concerns-the integrated water resources management.

The picture in figure five was blue (left) before the establishment of an adjacent CBP and now has turned not to ice white but to concrete white (right). This evident environmental impact needs attention and corrective measure like restoring the topography and the river channel and ultimately the stream itself. As the country has provisions to expand ecotourism on one side and the concrete industry is imposing such kind of impacts, there need to be a coordinated and clear development policy-based action. In fact, concrete wastewater has to be treated (de Paula et al. 2014) before discharge and this should be a primary task for the regulators to ensure if such industry do treat the wastes they release.



Figure 5. A photograph of surface change of an encroached urban stream, which is a year apart and the cemented gray layer is the place where stream used to flow (right).

3.5 The key informant interviews

In order to access technical and regulatory information, several batch concrete production industry-related institutions have been approached, especially those found in the two sub-cities of the CBP locations, for possible key information interviews. Unfortunately, the local administration staffs that are in charge of regulating such kinds of industries and even personnel in charge of such regulatory and permit issuance activities such as those in the “Minerals” department did not have an idea about CBPs and their EPHIs. Some were even amazed by the orientation provided during field activities about CBPs. Ultimately, based on proximity to the subject of the study, six people were selected purposively. The selectees were three people from AAEPa, one from Bole sub-city, one from Yeka sub-city and one from the community adjacent to two CBPs studied. Major issues considered in the checking stage, such as the key questions presented and the respective responses of the identified key informants, are summarized (Table 4).

Few have also described the subsequent question that asks to explain the changes made to urban streams due to CBPs; one respondent from the community and one from AAEPa have explained it well. The latter has technically explained the existing condition, citing the dumping of sediments and construction materials into the urban stream gorges. The informant from the community nearby has told the real experience that people had been bathing, cattle watering, collecting grass, and even sand in earlier times. But after CBPs came into operation, all services of the streams ceased, noting that currently clear water is not flowing.

The key informants, especially from AAEPa, have criticized the current waste management practices by the CBPs and have expressed their concern for the environment. Furthermore, the community side witnesses dust particles engulfing visible nearby inhabitants and the church nearby

for reasons the community is unaware of until recently it stops. Yet, dust and cement particles are mostly there following loading and unloading trucks movements.

Table 4. Presents the responses from the key informant interviews to selected questions regarding CBPs

Key question asked	KIL*	Key response
Regarding major waste generated by the CBPs	AAEPA	Dust, wastewater and solid waste, light, alkaline water, excess noise, aggregate waste discharged to land and water
	Community	Dust, especially some time before, sediment
	Sub city	Aerosol, washed out cement and mixture
Common uses of urban streams	All	Sanitation like washing clothes, agricultural uses like farming and cattle watering, bathing, drinking and cooking
If any of them noted any change on streams nearby CBPs		Yes=4 (one from AAEPA, three from community and sub cities) No=2 (all from AAEPA)
If the informants do think that CBP effluent can have EPHIs	ALL	Yes (n=6)
If there is any experience regarding effect for question 4	ALL	Yes=1 (AAEPA) No=2 Reserved/do not know=3
If they do think CBPs release the wastes directly into urban streams without any treatment		Yes =4 (two from AAEPA) No=0 Reserved/do not know =2

KIL= key informants' location

Looking at the range of the responses, it appears that the extent of being informed or aware about CBPs is so varied that it may prove the fact that there is still a lack of participative decision making in issuing permits to those process plants during impact assessment study stages. This can result in uncoordinated action thereby hampering the interest in an environmentally conscious sustainable city realization. Relatively, and as the position is expected, the respondents from the AAEPA are better aware of the magnitude of the problem and the existing environmentally unfriendly practices by the CBPs. However, it also appeared that the same respondents missed recognizing the fact that the same organization was authorized to issue such a mandate.

4. CONCLUSION

Results found in this study indicated the rapid increase of CBPs reaching 95 and being among the 470 construction input suppliers in Addis Ababa city. While the area occupied by those process plants is considerably high and their location is environmentally sensitive, the mandate for issuance of permits to CBPs is diffused, and little is known by the administrative and technical people there about CBPs. What makes it worse is that permits for CBP businesses are issued by different public bodies, such as the sub-city administrations, the trade and industry bureau, the bureau of mines, etcetera. Contrarily, the EPHIs of CBPs are perhaps vividly witnessed by the water pollution in the areas, the rivers or streams clogging, and the prevalent dust air pollution, which all demand the review of CBP permit issuance procedures. More importantly, clear mandates and guiding policy, as well as strong regulatory mechanisms, are crucial to manage the situations.

The existing operating conditions and hence the environmental performance of CBPs in Addis Ababa are environmentally unfriendly; the environmental health impact is evidenced by the complete alteration of fluvial systems that needs urgent attention. The CBPs are producing massive solid and liquid waste that is large enough to clog the streams and form instead large ponds of grey cement-containing wastewater, conquering the urban and perhaps vital streams to the level of distraction of natural environmental processes. The diffused and unclear responsibility and mandate of the regulatory sector have to be rectified, as there is no clear mandate even to issue permits to those CBPs considering at least their environmentally unfair location. Clearly, the CBPs deteriorated the quality of urban streams formed lagoons of concrete wastewater, alarming the need for a clear mandate as well as operational and accountability policies. Competent personnel within the concerned regulatory or administrative body have to be there. Even engaging the communities

living around such sites should have involvement in either preliminary assessment or the continuous monitoring and evaluation of CBPs. Given the alarming deteriorating effects of CBPs in the city area, mapping the green infrastructure and ecosystem conditions and thereby determining the status as well as projecting the effect is very important. Clear and specific state policy regarding the management of industrial wastes, including CBPs, is demanding. Further in-depth study to elucidate the long-term environmental impact of CBPs that include the hydrogeological phenomena has to be studied.

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STATEMENTS AND DECLARATIONS

Conflict of interest

The authors declare that the review was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author contributions

GDG conceived the idea, crafted and drafted the manuscript. SJA reviewed and added more on the manuscript. EDW co-crafted & reviewed the manuscript.

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Data availability

All data are included in the manuscript.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics

Not applicable

Consent to participate

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