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A economia circular como inovação contra a poluição dos rios Tietê e Pinheiros

Circular economy as an innovation against pollution of the Tietê and Pinheiros rivers

André Buono Silveira

Resumo

Este estudo examina a poluição severa dos Rios Tietê e Pinheiros na Região Metropolitana de São Paulo (RMSP), resultante da urbanização desordenada e do despejo de esgoto não tratado. Apesar de décadas de investimento, os esforços tradicionais de despoluição apresentaram resultados modestos. Baseado em uma revisão de literatura, este trabalho propõe a economia circular como uma estratégia inovadora para combater essa poluição. A implementação de princípios circulares – como redução de resíduos, recuperação de recursos e manufatura sustentável – pode reduzir significativamente as cargas de poluentes e é apresentada como vital para a restauração dos rios.

Palavras-chave: Economia Circular, Água, Poluição, Rio Tietê, Rio Pinheiros.

Abstract

This study examines the severe pollution of the Tietê and Pinheiros Rivers in São Paulo's Metropolitan Region (MRSP), resulting from disorderly urbanization and the discharge of untreated sewage. Despite decades of investment, traditional depollution efforts have shown modest results. Based on a literature review, this work proposes the circular economy as an innovative strategy to combat this pollution. Implementing circular principles – such as waste reduction, resource recovery, and sustainable manufacturing – can significantly reduce pollutant loads and is presented as vital for restoring the rivers.

Keywords: Circular Economy, Water, Pollution, Tietê River, Pinheiros River.

André Buono Silveira
Universidade Aberta, Lisboa, Portugal
0000-0003-4360-8342

Introduction

This work aims to discuss the environmental impact of the pollution of the waters of the Tietê and Pinheiros Rivers in the Metropolitan Region of São Paulo, Brazil (MRSP), in addition to presenting the circular economy as an innovative proposal to combat this pollution.

Research Question: How can the principles of the circular economy be applied to reduce pollution and improve the environmental health of the Tietê and Pinheiros Rivers in São Paulo? Hypothesis: The implementation of circular economy principles can significantly reduce the discharge of pollutants into the Tietê and Pinheiros Rivers by promoting the reuse of materials, minimizing waste generation, and encouraging sustainable industrial and urban practices.

The research was carried out through a literature review and a case study on the environmental conditions of these rivers.

Circular Economy

The idea of circular economy first emerged in 1990, where the interconnection between the environment and economic activities was initially studied. The definition of circular economy is not static as it contains a broad spectrum of principles and proposals (Merli, Preziosi, & Acampora, 2018).

In the thought of Geissdoerfer (2017), the circular economy is defined as follows:

> A regenerative system in which resource input and energy waste, emission, and leakage are minimized by slowing down, closing, and narrowing material and energy cycles. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, reconditioning, and recycling. Second, we define sustainability as the balanced integration of economic performance, social inclusion, and environmental resilience. (Geissdoerfer, Savaget, Bocken, & Hultink, 2017, p. 766).

The National Confederation of Industry (CNI) defines the circular economy as redesigning products and rethinking production, marketing, and consumption through reuse, remanufacturing, and recycling. It offers a sustainable alternative to the traditional linear model of production, consumption, and disposal (CNI, n.d.).

Great and increasing attention has been given to the topic of circular economy by academics and companies (Merli, Preziosi, & Acampora, 2018) and their approaches to "circular" business and the economic model, which assign slightly different emphases to the main components. Even so, they share several common principles, as indicated by (Weetman, 2019): a) Extend the life of materials and products, where possible, over several "use cycles"; b) Adopt the "waste = food" approach to help recover materials and ensure that biological materials returning to Earth are benign, not toxic; (c) retain the energy, water and other process inputs embedded in the product and material for as long as possible; d) Adopt systems thinking methods in the design of solutions; e) Regenerate or at least conserve nature and living systems and; f) Promote policies, taxes and market mechanisms that encourage product stewardship, for example, policies and norms of the "polluter pays" type.

Additionally, Klassen and Whybark (1999, as cited in (Erdiaw-Kwasie, Abunyewah, Yusif, & Erdiaw-Kwasie, 2023) discuss the concept of sustainable service, stating that "sustainable service involves the establishment of objectives, plans, and processes that determine the position of operations and the ability to respond to environmental issues and regulations". Authors now indicate the need to accelerate the process of promoting the circular economy, through the so-called circular disruption. A socio-technical system is needed that moves from the harmful "take-make-use-discard" model to more sustainable and socially desirable models that use circular strategies to reduce resource consumption and structural waste (Erdiaw-Kwasie, Abunyewah, Yusif, & Erdiaw-Kwasie, 2023).

The Environmental Problem in the Tietê and Pinheiros Rivers

São Paulo, Brazil, founded on January 25, 1554, remained a crossing point for drovers and pioneers until the end of the century. It was only from the mid-19th century that the city began to develop and grow in the wake of coffee cultivation and export. This growth is evidenced by the population evolution of the Metropolitan Region of São Paulo (MRSP) (Toledo, 2012; Waldvogel & Capassi, 1999), which grew from 28,500 inhabitants in 1881 to 15,198,900 in 1991 (Jorge & Salgado, 1996), reaching the current 22,048,504 inhabitants (BRASIL, 2022).

As the city grew, infrastructure challenges emerged. Trams, trains, public lighting, and utilities like water and gas were introduced. Avenues, bridges, and viaducts were built, and immigrants filled labor demands. To support expanding industries, electricity supply was prioritized. Additionally, flooded areas along the Tietê and Pinheiros Rivers were drained and urbanized to accommodate homes and businesses. Thus, it was decided, from 1937 onwards, to rectify the two, whose works took place from 1950 to 1960 (Pessoa, 2019).

The Metropolitan Region of São Paulo (MRSP), home to 22 million people across 39 municipalities, is one of the world's largest urban centers. Its rapid economic growth neglected environmental concerns, severely impacting the Tietê and Pinheiros Rivers.

For the analysis of the environmental condition of the mentioned rivers, the Water Quality Index (WQI), published by the Environmental Company of the State of São Paulo (CETESB), will be used. The WQI considers the following nine variables: fecal coliforms, pH, biochemical oxygen demand (BOD), total nitrogen, total phosphorus, temperature, turbidity, total residue, and dissolved oxygen. The WQI evaluation scale ranges from 0 to 100 points, classified according to Table 1, according to Appendix D (CETESB, 2020a):

Classification	Score
Excellent	79 < WQI <= 100
Very Good	51 < WQI <= 79
Regular	36 <WQI <=51
Bad	19 < WQI <= 36
Very Bad	WQI <= 19

Table 1. Classification ranges according to the WQI

The implementation of circular economy practices, such as waste reduction, resource recovery from waste, and reduction of pollutant discharges, could significantly improve the WQI of these rivers by reducing the BOD and nutrient loads.

The Tietê River

The Tietê River, the main river in São Paulo, stretches 1,100 km from Salesópolis to the Paraná River, flowing east to west. In 1937, local authorities rectified the river by filling floodplains and urbanizing its banks, enabling the construction of avenues and infrastructure.

After 45 km, the Tietê River reaches the city of Mogi das Cruzes, already in the RMSP where, from then on, for decades, it received the dumping of sewage and garbage without any treatment. It is estimated that the Tietê River received, by 2014, about 1,100 t/day of untreated sewage, of which 800 t/day came from residential and 300 t/day from industrial sources (Andrade & Melo, 2018). Currently, the estimate of the BOD/day load in the Tietê River basin, which indirectly represents the volume of sewage still discharged untreated, is in the order of 520 t BOD/day. According to the Environmental Company of the State of São Paulo (CETESB) which, among other attributions, monitors the quality of water in the State, the Tietê River has the following Water Quality Indexes (WQI) described in Table 2 according to Appendix M (CETESB, 2020b):

Station	2015	2016	2017	2018	2019	2020
02090	55	61	59	65	63	64
04200	15	17	16	17	20	23
02450	28	35	39	32	34	29
02600	72	84	81	82	75	82
02900	83	84	86	86	83	86

Table 2. WQI of the Tietê River – 2015/2020

It is noted that the river "dies" when it reaches the MRSP, whose measurement is indicated at stations 04200 and 02450, returning to present adequate WQI after 348km of passing through São Paulo, as measured at station 02600.

The Pinheiros River

The Pinheiros River, which extends for 25 km in the south of São Paulo, is a tributary of the Tietê River and was rectified in 1937 to urbanize its banks. During this process, a project was also created to reverse its course, allowing the formation of the Billings Dam, which supplies drinking water and generates electricity at the Henry Borden Plant, in Cubatão.

However, over the decades, the Pinheiros River has suffered from the dumping of sewage, garbage, and industrial waste, receiving little or no treatment. Currently, it is estimated that the BOD/day load in the Pinheiros River basin, which indirectly reflects the volume of sewage still discharged untreated, is approximately 95 tons per day. According to CETESB, the Pinheiros River has the following Water Quality Indexes (WQI) described in Table 3, according to Appendix M (CETESB, 2020b):

Station	2015	2016	2017	2018	2019	2020
04100	28	41	47	42	43	45
04250	17	17	21	20	27	28
04500	18	17	17	17	18	20
04900	16	17	15	15	15	18

Table 3. WQI of the Pinheiros River – 2015/2020

It is noted that throughout its length the Pinheiros River has contaminated waters and is unfit for consumption.

Aggressions to the Tietê and Pinheiros Rivers

From the researched bibliography it was possible to identify the following situations and relate them to the environmental problem of the Tietê and Pinheiros Rivers.

- Population increase (Crutzen & Stoermer, 2000) and (Gillings & Hagan-Lawson, 2014): The population increase in the Metropolitan Region of São Paulo (MRSP) occurred mainly at the end of the nineteenth century, driven by large migrations of European immigrants and people from other parts of Brazil in search of work. This resulted in higher water consumption and increased the need to use the Pinheiros River for energy generation.

- Intense urbanization (Crutzen & Stoermer, 2000), land-use change due to urbanization or traffic (Baede, Ahlonsou, Ding, & Schimel, 2001), land system change (Gillings & Hagan-Lawson, 2014): Urbanization and land-use changes in the São Paulo Metropolitan Region have driven rapid housing construction due to population growth. This expansion has had severe impacts on the Tietê and Pinheiros Rivers, primarily due to the discharge of untreated sewage.

- Physical modifications (Millennium Ecosystem Assessment, 2005; Bacelar-Nicolau & Azeiteiro, 2015): The river

rectification aimed to drain and urbanize banks for avenue construction. In the Pinheiros River, flow changes for power generation increased water speed, disrupted species reproduction, and removed natural flood-containment areas.

- Chemical pollution (Gillings & Hagan-Lawson, 2014): The release of chemicals and industrial waste into the Tietê and Pinheiros Rivers harms the ecosystem, worsened by São Paulo's industrialization. Poor agricultural waste disposal further degrades water quality and aquatic life.
- Emission of greenhouse gases into the atmosphere (Crutzen & Stoermer, 2000; Cavicchioli, et al., 2019): Polluted rivers like the Tietê and Pinheiros also emit greenhouse gases. Fertilizers and untreated sewage cause eutrophication, leading to fish deaths, foul odors, ecological imbalance, and methane and nitrous oxide emissions. Thus, the emission of these gases is a consequence of environmental pollution (Hao, et al., 2021; Schultz, 2021). It is important to mention that understanding the impacts on water, and the consequent interaction with the entire ecosystem, is challenging and significant (Sivapalan, 2011; Steffen, et al., 2004).

Impacts on Environment

Neglect of the Tietê River has led to lifeless stretches dominated by anaerobic bacteria. Industrial pollution and domestic sewage have degraded water quality, causing foul odors, flooding, and disease, prompting the population to demand action from authorities (Bueno & Henkes, 2016; Ribeiro, 2004).

Impact on water supply, irrigation, and fisheries

Urbanization and industrialization in São Paulo have deteriorated the quality of the waters of the Tietê and Pinheiros Rivers, due to the release of pollutants and untreated sewage. The failure in the collection and inspection system results in the death of fish and makes the waters unsuitable for supply, irrigation, and fishing. There is also a risk of contamination of groundwater near the Guarani aquifer. (Boehm, 2021; CETESB, 2020).

Impact on urban mobility in São Paulo

The irregular disposal of domestic waste in rivers causes serious environmental and social problems. The accumulation of waste in the riverbeds leads to siltation, intensifies floods and contaminates the water, harming aquatic fauna and flora. In addition, river pollution prevents the use of important waterways such as the Pinheiros and Tietê, aggravating urban congestion and generating excessive costs for society (Delijaicov, 2020).

Impact on people's health and the health system

River pollution, particularly heavy metals from untreated sewage, harms riverside communities by contaminating soil, water, and food, leading to illness in humans and animals. In the Tietê basin, toxic substances increase public health costs, damage the environment, and degrade biodiversity, negatively impacting the quality of life (Moraes, Mortatti, & Lopes, 2011; Ribeiro, 2004).

Impact on the social life of communities

Among the changes in lifestyle, the discontinuity of popular festivities, common on the waters of the Tietê, which on many occasions are no longer celebrated in view of the polluted waters and subject to causing diseases (Ribeiro, 2004).

Strategies for Minimizing Impacts

Efforts to decontaminate the Tietê and Pinheiros Rivers began in the late 1980s, with initial emphasis on the Tietê River. In 1992, the so-called Tietê Project effectively began, after strong social mobilization through a petition with

more than 1,200,000 signatures.

The first phase (1995-2000) involved US$1.6 billion to build 3,450 km of sewage network and install more than 1 million connections, benefiting 8.5 million people. The second phase (2000-2010) expanded the sewage treatment capacity and benefited 8.5 million people, with investments of US$2 billion. The third phase (2010) included the construction of another 1,350 km network and the installation of 718 thousand connections, increasing the treatment capacity by 42%, benefiting 5 million people. The fourth phase, which began in 2014, is underway and seeks to install 540 km of additional network and expand treatment capacity by 16%, benefiting 3.7 million people, at an estimated cost of US$900 million. In addition, integrated projects were launched, such as Tietê 2, Tietê 3 and Tietê 4, to connect the sanitation actions of the Tietê and the Pinheiros River (Ferreira, 2019; Camargo, 2018).

The Tietê Project showed positive results, with an increase in the sewage collection and treatment network in the MRSP. In 1992, 24% of the sewage of 15.4 million people was treated. In 2002, this percentage rose to 62% (17.9 million people), 70% in 2008 (19.2 million), 89% in 2019 and is expected to reach 92% in 2025, benefiting more than 22 million people.

The Novo Rio Pinheiros Project, started in 2019, aims to benefit 3.3 million people, connect 554 thousand properties to the sewage network and treat 4,600 L/s of sewage. It includes structuring works, interconnection networks, and improvements to existing facilities, like the Tietê Project, but focused on the Pinheiros River watershed (Ferreira, 2019; SÃO PAULO, n.d.).

Despite decades of investment, recent studies show that rivers remain polluted (Lavieri, 2021; Moraes N. G., 2022). The Tietê Project, aimed at improving water quality in the Tietê River and its tributaries, has yielded modest results considering the time and investment involved (Andrade & Melo, 2018). Therefore, it is proposed that combining the circular economy with traditional strategies could achieve the desired depollution outcomes for the Tietê and Pinheiros Rivers.

Circular economy can be integrated into the Tietê and Novo Rio Pinheiros Projects through techniques such as effluent treatment and reuse, recovery of nutrients (nitrogen and phosphorus) and heavy metals, and biogas production from organic waste. Reverse logistics and eco-design would reduce solid waste. These actions would decrease BOD, eutrophication, and contamination by toxic substances, improving water quality.

Possible Applications of the Circular Economy

The following aspects can be identified as benefits of the application of circular economy principles in the case of pollution of the Tietê and Pinheiros Rivers:

Reduction of solid/inorganic waste: The circular economy promotes sustainable production, leading to more durable products and reusable packaging, which reduces waste. However, improper waste disposal can still result in some waste entering rivers, carried by wind, rain, or inadequate sewage systems. Less waste overall reduces the likelihood of river contamination;

Reduction of chemical waste: sustainable production efforts also reduce the use, and consequently the disposal, of chemical components that often end up being discharged into the river without proper treatment;

Selective garbage collection: Selective garbage collection, a key feature of a sustainable city, helps reduce waste that could end up in rivers. The MRSP must make significant progress in this area as part of its efforts toward sustainability. While challenging, it is an achievable goal;

Innovation and New Technologies: The transition to a circular economy favors innovation by creating innovative solutions for the management of waste and pollutants, such as technologies that capture waste before it reaches waterways;

Education and Awareness: The implementation of the circular economy usually involves actions to educate and raise awareness among the population about the importance of correct waste disposal and environmental preservation, which can reduce pollution in rivers.

Industries and local businesses in São Paulo can adopt circular economy practices by incorporating recycled materials, improving resource efficiency, and minimizing waste through closed-loop systems. Incentives like tax reductions, subsidies, and green certifications can encourage businesses to switch to biodegradable or reusable packaging, directly reducing waste in rivers. Additionally, technology such as smart waste collection, real-time monitoring sensors, and advanced filtration can further prevent pollutants from reaching waterways. By combining sustainable manufact uring, policy incentives, and technological solutions, industries and businesses can play a crucial role in fostering a cleaner, more resilient urban water ecosystem.

Conclusion

The study addressed the pollution of the Tietê and Pinheiros Rivers, located in the Metropolitan Region of São Paulo (RMSP), and its environmental and social implications. The MRSP, one of the largest urban agglomerations in the world, faces serious problems related to population growth and disorderly urbanization, resulting in the uncontrollable dumping of sewage and garbage into the rivers. The Tietê River is the most compromised within the region, while the Pinheiros River has waters unfit for consumption along its entire length, reflecting a critical scenario of environmental degradation driven by years of neglect.

Pollution in urban areas is driven by growth, which seals soil and impairs rainwater runoff, causing flooding. River rectification and industrial waste disposal disrupt aquatic ecosystems and release greenhouse gases, worsening global warming. These issues negatively impact water quality, public health, urban mobility, and social life, limiting community events. To address pollution, strategies like waste removal and sanitation infrastructure have been introduced. Combining traditional methods with innovative approaches, such as the circular economy, is essential. This model minimizes waste and maximizes resource reuse through recycling, refurbishing, and redesigning products, creating a closed-loop system that reduces environmental impact and promotes sustainability.

Reducing waste and pollutants, improving selective garbage collection, and adopting innovative technologies can boost water recovery efforts. Raising public awareness and improving daily habits are crucial to ensuring environmental preservation is a shared responsibility, while promoting quality of life as a universal right.

In conclusion, circular economy strategies – such as waste valorization, resource recovery, and sustainable manufacturing – offer a transformative solution to combat pollution in the Tietê and Pinheiros Rivers. By integrating advanced technologies and fostering stakeholder collaboration, these practices can significantly reduce pollutant loads and improve water quality. However, challenges like policy gaps and funding limitations must be addressed. Future studies should explore scalability and long-term impacts, while immediate actions should focus on incentives, partnerships, and community engagement. Adopting circular economy principles is vital for restoring these rivers and building a sustainable urban future.

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