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CIRCULAR ECONOMY AND ITS INCORPORATION IN WATER TREATMENT PLANTS.

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Water is a vital resource for the development of all living beings. However, this resource is limited and increasingly scarce. The administration of water resources has been managed within the framework of a linear economic model. When water is part of the production process in different industries, its quality is compromised, and It's not always restored. It has been proved that industrial effluents affect ecosystems, degrading the natural environment. Circular economy is an alternative to solve this problem. This economic model aims to reduce waste that is produced and the amount of virgin raw material that is extracted from the environment. This article analyzes the benefits of implementing the circular economy model in water treatment plants.

Keywords: Linear economic model; circular economy model; sustainability.

ECONOMÍA CIRCULAR Y SU INCORPORACIÓN EN LAS PLANTAS DE TRATAMIENTO DE AGUA.

El agua es un recurso vital para el desarrollo de los seres vivos. Sin embargo, este recurso es limitado y cada vez es más escaso. La administración del recurso hídrico se ha manejado en el marco de un modelo económico lineal. Cuando el agua forma parte del proceso productivo en diferentes industrias, su calidad se ve comprometida y no siempre es restaurada. Está demostrado que los efluentes industriales afectan a los ecosistemas, degradando el medio natural. La economía circular es una alternativa para resolver esta problemática. Este modelo económico apunta a reducir los residuos que se producen y la cantidad de materia prima virgen que se extrae del medio. El presente artículo analiza los beneficios de implementar el modelo de economía circular en plantas de tratamiento de agua.

Palabras claves: Modelo económico lineal; modelo de economía circular; sostenibilidad.

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1. Introduction

According to the World Health Organization (2003), the minimum amount of water that a person should consume per day is at least 15 liters. However, in some undeveloped countries people do not reach that number. Contrary to this, in developed countries, a person consumes an average of 50 to 100 liters of water per day (Bartram & Howard, 2003). Water resources are unevenly distributed, in addition to this, anthropic activities are the main cause of water pollution worldwide (Goel, 2006). This not only reduces the amount of available resources, but also endangers the health of living beings and ecosystems (Delgadillo et al., 2011).

Due to the existing contamination, it is necessary that the water receive a treatment. For this, physical, chemical, and biological processes are carried out with the purpose of obtaining water with adequate characteristics for consumption or to return to a water body (Diseprosa, 2014). These processes are incorporated into the water treatment plants depending on the type of pollutant to be removed or eliminated. Also, the space available to implement the plant and the available budget must be taken into account (European Commission, 2001). Industries that produce difficult-to-treat or toxic pollutants must take responsibility for their effluents. Performing treatments is costly for them, and the incentives or sanctions for this to be implemented are not strong enough (Jesús & Mendonça, 2018).

The linear economy consists of "taking, making and throwing." The waste generated in the production process is not recycled or reused (Sariatli, 2017; Michelini et al., 2017). In this sense, the quality of the water is affected by the linear model, since the main interest is the profit and not the social and environmental good, and often the water is not treated properly or not treated at all (Flores et al., 2018). In order to remedy this situation, the circular economy model has been proposed, which consists of reincorporating waste into the production cycle (COM, 2014). In other words, once a product has reached its useful life, the industry will reuse its component materials to create a new one. It is a regenerative model, which reduces the amount of waste (Sariatli, 2017).

The circular economy concept can improve sustainability by restructuring consumption and production patterns using innovative designs and business models (Al-Saidi, Das, & Saadaoui, 2021). In topics of hydric resources, the circular model could optimize the efficient and sustainable use of water (Sgroi, Vagliasindi, & Roccaro, 2018). But there are few applications of the circular economy model in sectors such as water treatment (Abu-Ghunmi et al., 2016). The incorporation of the circular model in water management would bring many advantages such as saving some resources and energy (Tecnoaqua, 2018). In this sense, wastewater would not be seen as waste, but as a valuable unconventional resource (Abu-Ghunmi et al., 2016). In addition, it should be noted that water recycling is an alternative that can reduce the pressure on water resources and guarantee the water supply in regions that suffer from water scarcity (International Water Association, 2016; Moya-Fernández et al., 2021).

In this study, the concepts of lineal economic model and circular economic model will be detailed in order to analyze the contrast that exists between them. Cases of circular economy in industries will also be seen, to finally be able to analyze how this model could be implemented in water treatment plants.

2. Methodology

The methodology used for this research is the exploratory and explanatory method (Mauldin, 2020). For this, the information will be searched in the recognize bibliographic databases SCOPUS, Web of Science, and Google Scholar. Also, officially published documents of international organizations such as the World Bank and the World Health Organization will be considered. The review will be focus on the period 2000 to 2020. Once the information has

been collected and analyzed, the study will be developed in 4 parts. In the first place, the concepts of circular economy will be exposed to analyze the advantages it has compared to the linear economy model. As a second part, the benefits of the implementation of the circular economy model in the industrial area will be presented, describing case studies of the agricultural, mining, textile, and hydrocarbon industries. Third, examples of transnational companies with great impact on the world economy, which have incorporated the circular economy model, will be shown. Finally, the guidelines to implement the circular economy model in water treatment plants will be determined, exposing the benefits that this can bring. This makes visible the link between the industrial and water treatment plants, leading both towards sustainability.

3. Development and results

In this section, a comparison between linear economy and circular economy models will be shown. Cases of industries that have adopted the circular economy will be analyzed, identifying the advantages and disadvantages of the model. Finally, the strategy to implement the circular economy model in water treatment plants and the benefits that this would bring will be presented.

3.1. Comparison of the linear economy and circular economy model

The economy studies the way in which society manages its resources and the relationship they have with satisfying its needs. The needs that arise are limitless, but the resources are not. ‘‘Scarcity is not a technological problem but rather a disparity between human desires and the means available to satisfy them’’ (Mochón & Becker, 2000). Then, driven by the desire to satisfy needs, the linear economy model was born. This model is quite old, being a result of the industrial revolution. At this time, it was believed that many of the resources were infinite, without taking into account the problem that this could cause later, nor the environmental impact that uncontrolled industrial activities would have (Hermida & Domínguez, 2013).

The linear model consists of extracting raw material, processing to transform it into products, sell them and finally be discarded. Essentially the products after fulfilling their function become garbage, which ends up in a final disposal site. The final dispositions are not necessarily chosen correctly, which has generated environmental pollution (Garcés et al., 2019). In addition, its production generates a large expenditure of energy and resources that are part of the process. The purpose of this model is to generate infinite profits, regardless of the impact this may have on the environment (Falappa, Vazquez & Lamy 2019). Although this model has been successful in the 20th century, generating quite a bit of profit has proven to be unsustainable (Alqassimi & Upadhayay, 2019). There is increasing pressure on the environment. The population grows at an accelerated rate, at some point it will be impossible to have the amount of resources to cover all its needs. In addition, there will be a large amount of waste that will be unfeasible to transform and/or treat (Sariatli, 2017).

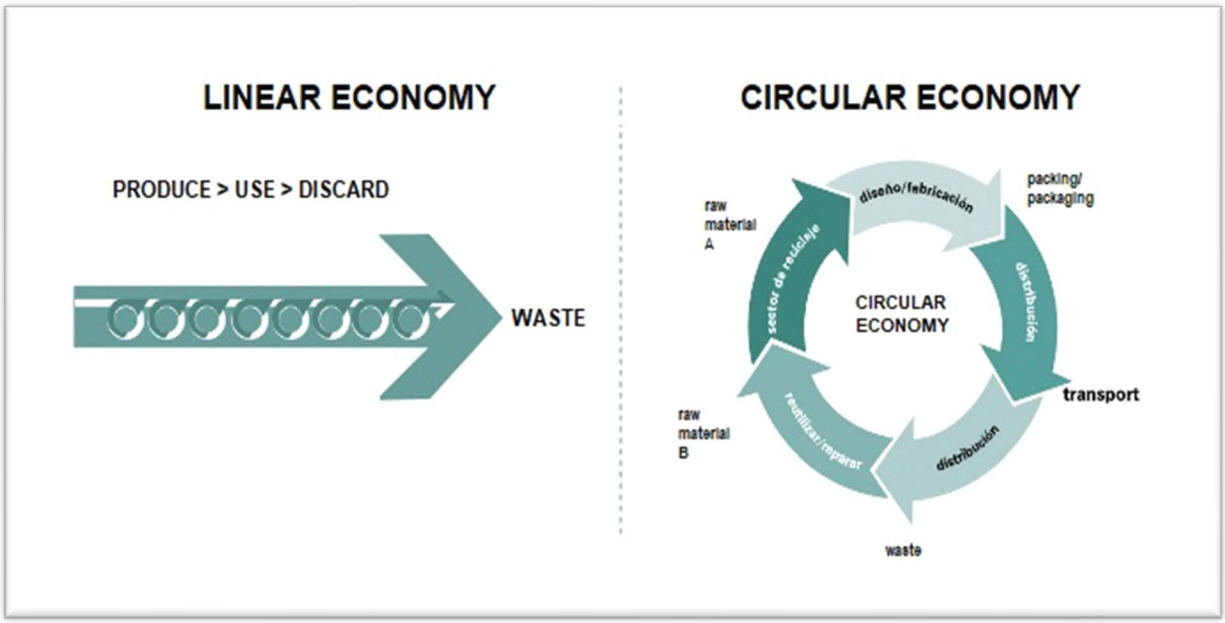
In contrast to this model, the circular economy was born. A model whose first guidelines began in the 70s. Later, in the early 2000s, the term *‘‘Cradle to cradle’’* was born, proposed by the architect McDonough and the chemist Braungart (2002). In this model, waste can be used as raw material and reinserted into the production process. Which generated a positive impact on the production chain and a better use of raw materials (Cerda & Khaliova, 2016). Making products of greater durability and quality facilitates that the materials can be recovered efficiently and no extra waste is generated. Over the years the model that includes these practices was called the circular economy (Hermida & Domínguez, 2013).

The circular economy is considered restorative and regenerative. This model consists of re-incorporate the products, which have reached their useful life according to the consumer's criteria, into the production cycle. That is, it seeks that the transformed materials and the

resources used as part of the process maintain their value. The purpose of this is to reduce the amount of waste that is produced, generating environmental and social benefits (Espaliat, 2017). It also reduces the amount of supplies and natural resources used to create products. This also releases pressure on the environment and less energy is used. These reasons make it a better alternative in contrast to the conventional linear economy model (Hermida & Domínguez, 2013).

Figure 1 shows the linear and circular economy models, in this it can be seen the clear differences between both models.

Figure 1: Linear model vs. Circular model



Source: Ellen Macarthur Foundation, 2013.

3.2. Advantages and disadvantages of the circular economy model in industries

The environmental problems that exist today create the need to migrate to more sustainable practices (Córdoba & Mercado, 2005). To achieve this, the circular economy is proposed, which has great benefits for industries, which will be mentioned below.

The circular model promotes the use of renewable energies. Although their implementation can be costly, their use has a lower cost than non-renewable energy sources (International Renewable Energy Agency, 2019). This reduces dependence on fossil fuels to generate energy and reduces the amount of greenhouse gases that are produced. Likewise, the loss of materials is reduced. This makes the production process more effective. It generates savings on the purchase of raw materials and the risks of shortages or volatility in prices are reduced. In addition, reduced the amount of produced solid waste (Espaliat, 2017). The model also promotes better management of water resources. Companies are encouraged to treat their effluents. In this sense, water can be recirculated and/or recycled in the production process, in order to reduce the amount of water used from the supply (Moreno, 2019).

While the model has many benefits, it also has disadvantages. Implementing the model is costly in the short term. Many of the materials would have to travel long distances to be treated, which represents an additional cost. Likewise, the lack of cooperation between clients and companies can be a potential risk to carry out the model. An industry may not treat all the waste it generates and needs another to treat and / or transform it. For this, symbiotic

relationships must be created between companies and have the objective, not only of generating profits, but also of ensuring the common good (Korhonen, Honkasalo, & Seppälä, 2017). Also, policies should be generated that facilitate the transport of materials and campaigns that inform and encourage people to participate in these practices.

It is important to mention that there will be waste that cannot be recycled. Many of the industries will have hazardous waste, or not suitable for some processes. For that reason, the industry must work with those in charge of waste management and give them an adequate final disposal (Sánchez & Cruz, 2012).

Table 1 presents a summary of the advantages and disadvantages of the circular economy model.

Table 1: Advantages and disadvantages of circular economy

Advantages	Disadvantages
Generates added value in waste. Reduces costs in raw materials. Reduces energy costs. Reduces dependence on fossil fuels. Reduces the amount of solid waste. Promote sustainable practices. It generates a social-environmental responsibility.	Short-term expenses to implement the model. Lack of cooperation between companies and client - company. Expenses in treatment or final disposal of some materials.

Source: Own elaboration, 2021.

In brief, the circular economy is a model that proposes solutions to the problems that were observed in the application of the linear economy. The implementation of a circular model still has certain limitations, but these are less than their advantages. Considering the current degradation of the natural environment, the urgent need to seek an orientation towards sustainability is denoted.

3.2.1 Implementation of the circular economy model

Five interesting cases of transnational companies that have implemented this model in their production process are presented in Table 2. These transnationals are important because of the global impact they generate in terms of the economy and employment worldwide.

Table 2: Companies that use circular economy

Company	Description	Source
Apple Inc.	This American company manufactures electronic products. When one of their cell phones reaches its useful life, the buyer can return it to the company. This will result in a discount for a future customer purchase and the materials are recycled to be used in new cell phones.	Apple (2019) Material Impact Profiles.

The Coca-Cola Company	This American company produces beverages in almost all countries. Their distribution is done in plastic bottles; however, the company is in charge of collecting their bottles and recycling them, thus reducing the amount of the waste they produce. In addition, the company has water treatment plants in several countries.	The Coca-Cola Company (2019) How and why Coca-Cola supports recycling in the U.S.
BMW	The German car company reconditions used parts of its cars and sells them at a lower price. They also promote the use of recycled materials to make parts for new vehicles.	BMW (2020) Circular economy @ BMW GROUP.
IKEA	IKEA is a Swedish company that manufactures furniture, mattresses, appliances and other household products. The company is committed to using the circular economy in all its processes until 2030. They currently use quite a few recyclable materials and take advantage of various wastes in the production chain.	IKEA (2021) Why the future of furniture is circular.
Nike	The American company manufactures shoes, balls and other sporting goods. When these are discarded, the company recovers this waste to crush it and turn it into other products in partnership with other companies.	Nike (2021) Circular Innovation Challenge.

Source: Own elaboration, 2021.

The circular economy has gained ground in recent decades. Proof of this is the growth in its implementation in major companies around the world. However, there are still areas where it has not yet been incorporated, such as in water treatment plants, whether they are wastewater plants or water treatment plants. Its incorporation in the previous ones must be analyzed and considered to achieve sustainability. The way to achieve this is the adoption of the general and binding circular economy model within all human activities.

3.3. Circular Economy Implementation Strategy in water treatment plants

As mentioned before, water resources are very important and scarce. This is why it is important that this resource can be reused or reincorporated into the production cycle, as proposed by the circular economy. Water resources must be well managed so that they are used in the most efficient way possible. All effluents must be taken into account as part of the supply chain, for which they must receive treatment. Treatment plants have a series of processes whose purpose is to reduce pollutants in the water. In order to have a good management, according to the circular model, all the by-products that are generated in the treatment must be used (Moreno, 2019).

Better use of wastewater and its treatment by-products is in line with Sustainable Development Goals 6 and 12. Goal 6 ‘‘Clean water and sanitation’’ seeks to reduce water stress in different

countries and guarantee that all people have access to drinking water. Goal 12 ‘‘Responsible consumption and production’ ’seeks to reduce the ecological footprint through better production habits (PNUD, 2015). Next, in Table 3, some examples of strategies for the use of waste in water treatment plants are presented.

Table 3: Use of waste in water treatment plants

Treatment stages	Processes	Waste	Exploitation strategy
Primary treatment	Physic	Inert sludge	● As long as the inert sludge is considered non-hazardous, dry the sludge so that it can be used as a raw material for bricks, clay or cement. ● Recirculate the recovered effluent.
Secondary treatment	Physicochemical	Inert sludge	
Tertiary treatment	Biological	Aerobic: Inert sludge	● Dry the sludge so that it can be used as a raw material for bricks, clay or cement. ● Recirculate the recovered effluent.
		Anaerobic: Sludge with organic load	● Stabilize the sludge to transform it into fertilizers. ● Build biodigesters to produce biogas.
Advanced treatments	Reverse osmosis	Inorganic substances	● Recover inorganic substances through advanced methods, with the aim of giving them added value.
	Ion exchange	Resins with mineral contain	● Recover the resins through demineralizing processes. ● Treat effluent in hot softening or reverse osmosis plants.

Source: own elaboration based on; Argudo, Molina, & Leyva, 2017; Lago, Fernández, & Diaz, 2005; Lopez, 2010; Mazille & Spuhler, 2020; Muñoz, 2016; Neczaj & Grosser, 2018; Rodríguez et al., 2017.

An essential step so that the water can be used again is disinfection. The pathogenic microorganisms present in the water are eliminated. However, the quality of it may not be suitable for consumption, that is, drinkable. But it can be used for agriculture and land irrigation, industrial purposes, flushing toilets, if there is an adequate drainage system and replacement of groundwater (Neczaj & Grosser, 2018; World Bank, 2020).

3.3.1. Benefits of implementing the circular economy model in water treatment plants

If the circular economy model is applied to water treatment plants, whether for wastewater or purification, the use of the water resource and the waste generated in the different processes will be guaranteed in the optimal way. Treating the largest amount of water allows greater availability for consumption, therefore putting less pressure on the effects of water scarcity (Moreno, 2019). Incorporating a circular economy model into water treatment plants creates a participatory environment that could link the plants and the various industries seeking to achieve sustainability. Table 4 shows some examples of links that could be generated between companies and water treatment plants, generating a symbiosis between them.

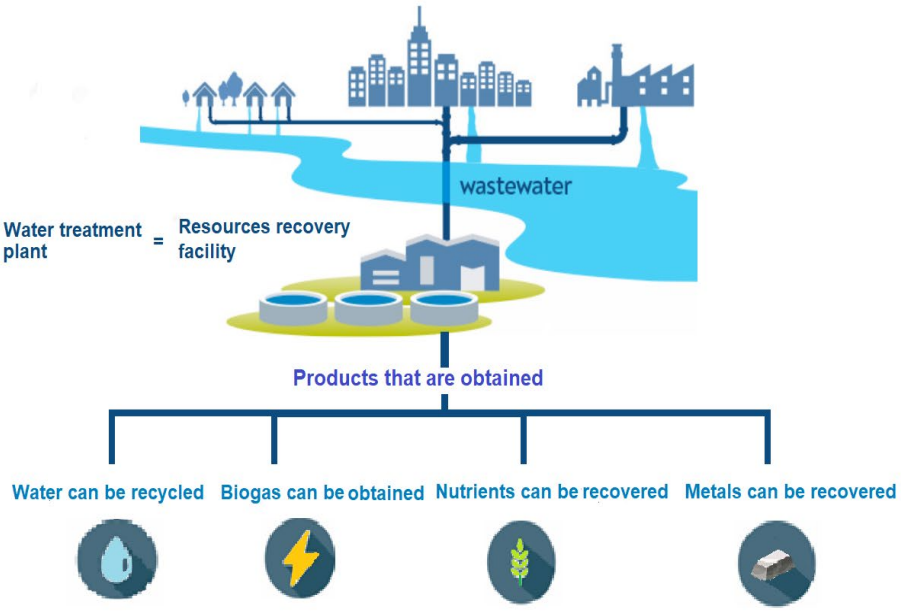
Table 4: Linkage activities between industrial companies and water treatment plants

Industry	Linkage
Agriculture	Agricultural companies could acquire nutrients for the soil, resulting from tertiary treatments.
Mining	Mining companies could invest in the treatment plants in exchange for the recovery of metals from their effluents.
Hydrocarbons	Companies could encourage biogas to be obtained as a result of tertiary treatments, thus depending less on gas wells.
Textile	Companies can use treated water for their industrial processes instead of water from the supply network, for a lower price.

Source: own elaboration based on Flores et al., 2018 and Melgarejo, 2019.

In order to clarify the examples previously mentioned. They have been illustrated in figure 2.

Figure 2: Products that are obtained from a water treatment plant



Source: Redraw from World Bank, 2020.

4. Conclusions

The case studies analyzed show good results in the application of the circular economy model in several transnational companies. The main benefits of this model are the generation of extra income through savings in raw materials, energy, as well as the valuation of waste. The foregoing suggests that the circular economy model economically favors the companies that apply it, and at the same time it would achieve industrial sustainability in favor of the environment.

It should be noted that the different industries and water treatment plants are intrinsically linked. In this sense, both must operate together, seeking a symbiosis that can benefit both the company, society, and the environment, only in this way will a global circular economy be achieved.

Opportunities for the use of waste from water treatment plants were identified. Among the most important are the potential for biogas generation through organic sludge, and the use of non-hazardous inert sludge as raw material for construction. In addition, the recovery of valuable inorganic substances that are concentrated in advanced treatments is also possible, but this usually involves a significant extra expense so it must be analyzed carefully.

Future research, related to the design of treatment plants, whether for wastewater or purification, should not only aim at optimizing the efficiency and costs of the treatment, but should at the same time seek the best use of the waste generated. It is necessary to change the paradigm in which contaminated water is perceived as a problem towards an opportunity for sustainable development.

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