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Reuse of water and sludge in agriculture: new technologies for the treatment

Reúso de água e lodo na agricultura: novas da tecnologia para o tratamento

Reutilización de aguas y lodos en agricultura: nuevas tecnologías para su tratamiento

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Samuel Cassiano Fernandes
ORCID: https://orcid.org/0000-0003-4447-6716
Universidade José do Rosário Vellano, Brazil
E-mail: samuel.fernandes@aluno.unifenas.br
Ana Maria Santana do Amaral
ORCID: https://orcid.org/0000-0001-5150-9462
Universidade José do Rosário Vellano, Brazil
E-mail: ana.amaral@unifenas.br
Willian Aparecido Leoti Zanetti
ORCID: https://orcid.org/0000-0002-3723-7437
Universidade Estadual Paulista, Brazil
E-mail: willian.zanetti@unesp.br
Fernando Ferrari Putti
ORCID: https://orcid.org/0000-0002-0555-9271
Universidade Estadual Paulista, Brazil
E-mail: fernando.putti@unesp.br
Bruno César Góes
ORCID: https://orcid.org/0000-0002-4409-1720
Universidade José do Rosário Vellano, Brazil
E-mail: bruno.goes@unifenas.br

Abstract
The treatment and reuse of water in Brazil is one of the most discussed issues in the agricultural field. In recent years, the scarcity of water changes in the rainfall regime has impacted production. The management of water resources aims to make better use of one of the means that most uses water, agriculture. Reuse and treatment are essential through innovative technologies that corroborate better water efficiency to extract the maximum water capacity and avoid waste. In an increasingly sustainable scenario, which seeks cleaner environments, with little or no emission of pollutants and losses of water resources, the reuse and treatment or possible disposal in a correct way is always an object of study to achieve the effect in use. of water, seeking better production in crops and reducing environmental impacts. This work aims to analyze the historical evolution of technologies used to treat wastewater and sewage sludge. We can see that the theme has grown in recent years, and several technologies are emerging to improve water treatment more efficiently and effectively. Thus, we conclude that the reuse of wastewater and sewage sludge has a large field of study and application in agriculture.
Keywords: Efficiency; Water; Wastewater; Agriculture; Productivity.

Resumo
O tratamento e reaproveitamento de água no Brasil é um dos assuntos mais discutido no âmbito agrícola, pois nos últimos ano a escassez de água, mudança de regime de chuvas tem impacto na produção. O manejo de recursos hídricos tem por objetivo um melhor aproveitamento em um dos meios que mais utiliza a água, a agricultura. Buscando extrair ao máximo da capacidade hídrica e evitar desperdícios, se torna extremamente necessário o reaproveitamento e o tratamento, por meio de tecnologias inovadores que corroboram com uma melhor eficiência hídrica no país. Em um cenário cada vez mais sustentável, que busca meios mais limpos, com pouca ou nenhuma emissão de poluentes e perdas dos meios hídricos, a reutilização e o tratamento ou possível descarte de forma correta, é sempre objeto de estudo para alcançar a efetividade no uso da água, buscando uma melhor produção nas lavouras e reduzindo os impactos ambientais. Esse trabalho tem como objetivo analisar a evolução histórica de tecnologias empregadas para o tratamento de água residuária e lodo de esgoto. Podemos verificar que a temática tem crescido nos últimos anos e diversas tecnologias estão surgindo para melhorar de forma mais eficiente e eficaz o tratamento de água. Assim, concluímos que o reaproveitamento de água residuária e lodo de esgoto tem um grande campo de estudos e de aplicação na agricultura.
Palavras-chave: Eficiência; Água; Água residuária; Agricultura; Produtividade.

Resumen
El tratamiento y reúso de agua en Brasil es uno de los temas más discutidos en el campo agrícola. En los últimos años, la escasez de agua y los cambios en el régimen de lluvias han impactado la producción. La gestión de los recursos hídricos pretende hacer un mejor uso de uno de los medios que más utiliza el agua, la agricultura. La reutilización y el

tratamiento son esenciales a través de tecnologías innovadoras que corroboren una mejor eficiencia del agua para extraer la máxima capacidad de agua y evitar el desperdicio. En un escenario cada vez más sostenible, que busca entornos más limpios, con poca o nula emisión de contaminantes y recursos hídricos, la reutilización y el tratamiento o posible eliminación de forma correcta es siempre objeto de estudio para conseguir el efecto en el uso. de agua, buscando una mejor producción en los cultivos y reduciendo los impactos ambientales. Este trabajo tiene como objetivo analizar la evolución histórica de las tecnologías utilizadas para el tratamiento de aguas residuales y lodos de depuradora. Podemos ver que el tema ha crecido en los últimos años y están surgiendo varias tecnologías para mejorar el tratamiento del agua de manera más eficiente y efectiva. Por lo tanto, concluimos que la reutilización de aguas residuales y lodos de depuradora tiene un amplio campo de estudio y aplicación en la agricultura.
Palabras clave: Eficiencia; Agua; Aguas residuales; Agricultura; Productividad.

1. Introduction

According to Empresa Brasileira de Pesquisa Agropecuária (Embrapa, 2021), water is a finite natural resource and one of the biggest concerns for the future of society. In this way, humanity increasingly questions how its use has been carried out by the various product areas in the world.

The need to study water connections in plants is due to the variety of physiological and ecological attributions that water plays. Water is the most numerous and the most limited among the resources that plants need to grow and function. In this way, both the spread of vegetation on the land surface and agricultural productivity are regulated significantly by water availability (Kerbauy, 2004). Thus, water is essential for plant life, both in a biochemical and biophysical sense, and its influences are internal and environmental (Benincasa & Lima, 2004).

The protection of the environment and water resources is a requirement worldwide. Of the 2/3 of the land, 97% is saltwater and 3% freshwater. Of these, 2% are in the form of ice at the poles and icebergs, with 1% of continental water, most of which is groundwater, leaving approximately 0.001% in steam. In addition to the low amount of water that can be converted into rainfall, there is also poor distribution, which sometimes causes irreparable consequences, as in the case of Northeast Brazil, which has a distribution concentrated in a few months of the year (Peixoto, 2020).

Water is an increasingly scarce resource and a condition motivated primarily by waste and the progressive demand resulting from increased population. In this context, agriculture consumes 87% of the world's water resources, and the lack of this resource has a significant impact on the economy (Goellner, 2015). According to the National Water Agency (ANA) projections, water consumption in Brazil, including all segments, should increase by 24% by 2030. The agricultural sector will drive this increase.

Water is becoming increasingly scarce, not only in arid regions but also in regions where rainfall is plentiful. This lack concerns, especially the quantity, disposition, and quality of this water, as polluted water resources are unavailable and unsuitable (Barros & Amin, 2008). There is a lack of balance between the availability, demand, and conservation of water quality, with inter-regional and international conflicts concerning ownership and right to use water being notable (Pereira et al., 2002).

To face water scarcity, technologies must be implemented to acquire cleaner water, reduce waste and excess consumption, reuse and conservation strategies, and protect springs and surface and underground reserves at the local, regional and global levels (Fernandes et al., 2008).

According to United Nations Children's Fund (UNICEF), less than half of the world's population has access to safe drinking water. Irrigation corresponds to 73% of water consumption, 21% goes to industry, and only 6% is for domestic consumption.

Even comfortable with United Nations (UN) standards, water distribution in Brazil suffers from extreme inequality. Around 80% of all Brazilian water availability is concentrated in the Amazon region alone, according to 2012 data from the National Water Agency (ANA) (Brazil, 2013).

Aiming at the maintenance of water resources, there are numerous training courses and manuals published by government agencies that seek to bring relevant information about the importance of the rational use of water in agriculture, which today totals a percentage of 70% of all water consumed in Brazil (Embrapa,2018).

Another major problem in the agricultural sector is pollution, where pesticides, material disposal made incorrectly, and lack of management cause a high level of corruption, even indirectly. Today, even after ten years of the creation of the Basic Sanitation Law, Law No. 11,445/07, which establishes the procedures for basic sanitation throughout the country, we still have about 35 million inhabitants without access to water, and 40% of all sewage produced is treated, where the other 60% is still discharged into water bodies without proper treatment (Embrapa, 2018).

Planning water management in agriculture is the first step towards optimizing water consumption and correcting processes that may generate waste. Efficiency in water use can collaborate to solve scarcity problems, reducing conflicts between users and increasing, stabilizing, and guaranteeing production (Faggion et al. 2009). In this way, making adequate water use in agriculture can avoid several setbacks (Rodrigues, 2005).

Given the above, the objective of the present work is to identify the evolution of water management techniques, created, discovered, and already used, for a scenario that already becomes so real in our daily lives.

2. Methodology

This research used data extracted from the National Institute of Industrial Property (INPI) between 1975 and 2021 to validate the facts. It was possible to verify the total number of patents already deposited for the reuse and treatment of water and their evolution over time about the technologies created and applied in the field. We seek truthful data, which validate the information presented with assertiveness and efficiency.

In this sense, the INPI manual was used, which informs which sectors comprise it. We focus on section C, which deals with chemistry and metallurgy, wherein numerology two deals specifically with water, waste, sewage, and sludge treatment. In this group, we address the nomenclature ending in F, which refers to Processes for making chemical substances harmful, harmless, or less harmful by effecting a chemical modification in implications; Separation, settling tanks or filter devices; Special provisions on watercraft of installations for the treatment of water, wastewater or sewage, e.g., to produce fresh produce; Adding materials to the water to prevent corrosion; Treatment of radioactively contaminated liquids.

The subclasses are presented through the numbers listed below:

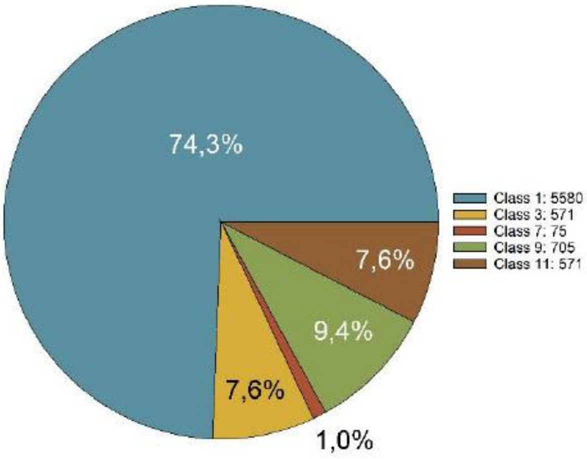
- CHEMICAL OR PHYSICAL TREATMENT with numerology 1/00 and 5/00;
- BIOLOGICAL TREATMENT with numerology 3/00;
- AERATION OF STRETCHES with numerology 7/00;
- MULTIPLE TREATMENTS with numerology 9/00;
- SLUDGE TREATMENT with numerology 11/00.

3. Results and Discussion

During the analyzed period, 7,370 patents were filed with the Industrial Property Institute (INPI) referring to technologies for water treatment.

In this sense, 5,480 deposits referring to chemical or physical treatments were found, grouped in subclass C02F 1/00 and C02F 5/00, representing 74.3% of the records made in the period. In turn, 560 patents were registered for biological treatment, 73 for the stretching aeration process, 697 for multiple therapies, and 560 for sewage sludge treatment (Figure 1).

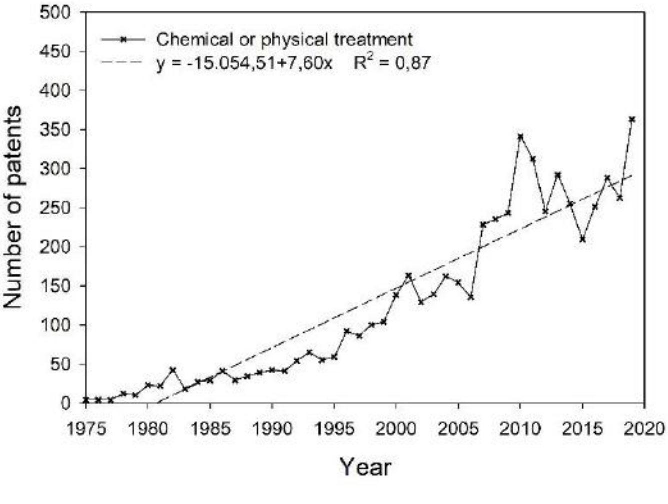
Figure 1 - Demonstrate the total number of patents and the subclass proportion.



Source: Prepared by the authors.

We observed a great preponderance in chemical or physical treatment patents, covering more than 2/3 of the total number of patents produced from 1975 to 2020. less has been patented, with a share of only 1% of the total amount of patents ever created. In this sense, Figure 2 illustrates the behavior of the evolution of the number of patents related to chemical and physical treatments.

Figure 2 - Evolution in the number of patents created for Physical or chemical water treatments Code Group: C02F 1/00 and C02F 5/00

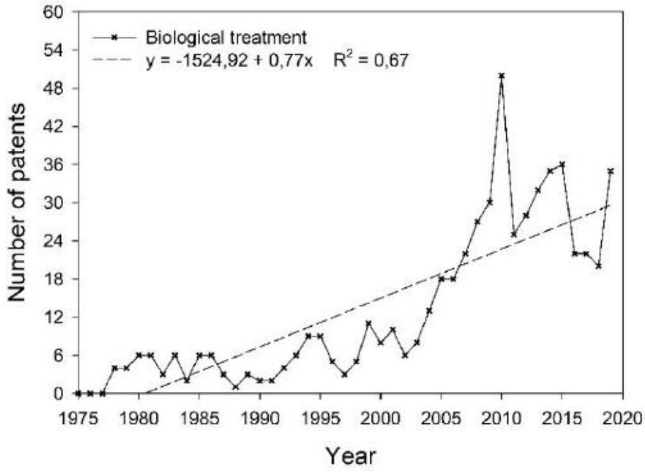


Source: Prepared by the authors.

In Figure 2, we see the evolution of chemical or physical treatment patents. However, we can observe a constant development, which is justified due to the significant growth of research technologies and materials elaboration, with considerable oscillation. There was an increase in the years from 2007 to 2010, corresponding to about 235% about the year 2005 and also a substantial decrease of the years from 2011 to 2015, which was about 43% about the year 2010, but with abrupt resumption levels previously established and still reaching a new top in the number of patents, which corresponds to an increase of 187% compared to 2015. We can also verify the coefficient of determination (R^2) that shows through the data a high level of fidelity about the equation of the straight line and the trend line.

Figure 3 shows the behavior in the period of innovative technologies for the biological treatment of water.

Figure 3 - Evolution in the number of patents created in Biological Water Treatment Code Group: C02F 3/00.



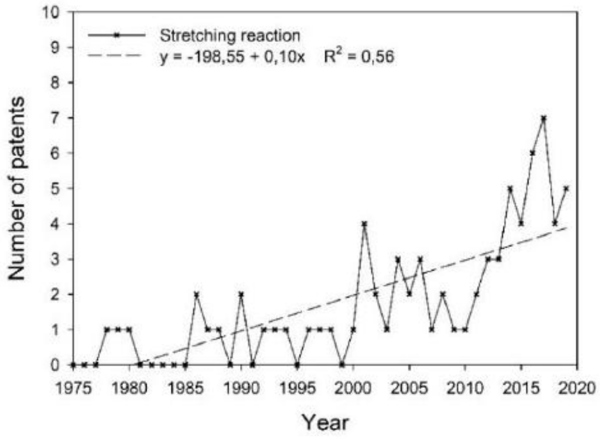
Source: Prepared by the authors.

Figure 3 only represents the patent data on biological treatment. Even without a coefficient of determination (R^2) close to 1 about the trend line and the equation, we observed an increase in the number of patents over the years, even with some fluctuations.

With an emphasis on the years between 2006 and 2018, in which, between the years 2006 and 2010, we had a growth of 300% compared to 2005 and a significant drop between the years 2011 and 2019, thus a decrease of about 51% compared to 2010. As in the chemical or physical treatment data, biological treatment experienced a substantial increase after 2005.

Figure 4 represents the behavior of technologies in Elongation Aeration for water treatment between the years 1975 and 2020.

Figure 4 - Evolution in the number of patents created in Elongation Aeration. Code Group C02F 7.00.



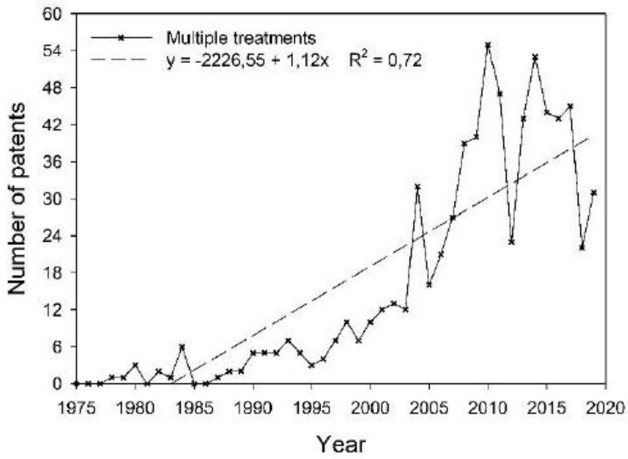
Source: Prepared by the authors.

Figure 4 shows the evolution from 2011 to 2018 for the patents created on stretching aeration. This evolution was late about the groups with codes C02F 1/00 and 5/00, and C02F 3/00, which started increasing in 2005, showing minor drastic declines concerning the other two forms of treatment of previous water.

This also proves to be the only one of all the forms of treatment that showed a lower level of fidelity about the trend line and the equation, having a coefficient of determination (R^2), showing only 56% of readjustment. However, even with some differences, it presented constant evolution, as demonstrated by the trend line.

In addition, Figure 5 represents the patents referring to multiple treatments for the reuse of water during the period studied.

Figure 5 - Evolution in the number of patents created in the Multiple Treatments Code Group C02F 9/00.

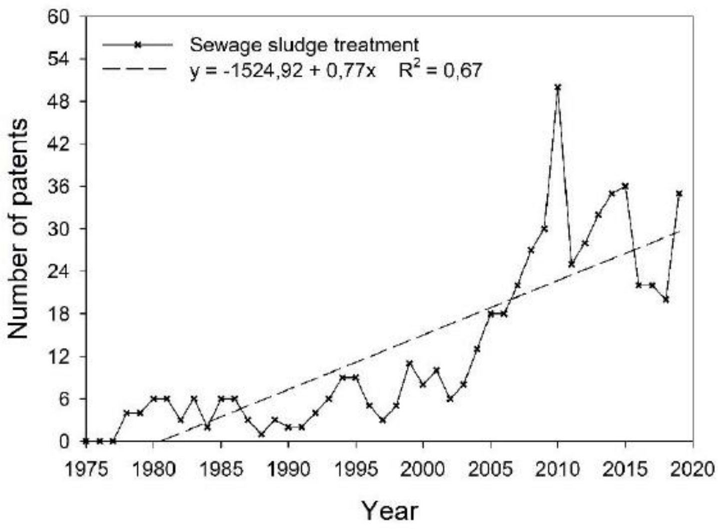


Source: Prepared by the authors.

The Figure presents the patents developed on the multiple treatments, in which it has a higher level of oscillation than the other models of water treatment. This variation was observed prematurely about groups with codes C02F 1/00 and 5/00, and C02F 3/00; started in mid-2003, and since this fluctuation in the number of patents, it has never returned to the 2005 numbers. We also noticed a good relationship in the coefficient of determination (R^2) which showed a level of fidelity of 0.72 about the formula and the guidance line and a significant slope demonstrating a solid uptrend.

In turn, Figure 6 illustrates the creation of patents in the period studied in relation to Sewage Sludge Treatment for the reuse of water.

Figure 6 - Evolution in the number of patents created in the Sewage Sludge Treatment Code Group C02F 11/00.



Source: Prepared by the authors.

Considering Figure 6, we can verify a good coefficient of determination (R^2) that showed a level of fidelity and an adjustment about the trend line and the equation in the value of 0.67. We also observed a positive variation from the year 2003 similar to the group with the code C02F 9/00, however, with a trend line that does not slope strongly about the other group and has a single considerable variation in 2010.

4. Final Considerations

In this work, we delve into the current scenario about water use, with water scarcity, pollution of tributaries, waste of water resources. The role of technologies for preserving and maintaining river levels and the importance of water for agriculture today plays a fundamental role in our food.

We conclude, therefore, that we are living in a moment of technological evolution, with patents that seek physical, chemical, biological means, aeration by stretching, and multiple treatments to reuse these resources as much as possible. New queue technologies make it possible to treat the sewage generated in households and industries. We are making it possible to return water with less waste to the environment and reduce our water resources' impact.

And we also observe the reason why the competent bodies are so concerned, and we realize that there is a constant population increase and the water demand will be even greater. Because our reserves are scarce concerning the entire amount of all the water on the planet that in the future, the need for water will exceed the supply because it will not be able to supply it, if we do not make better decisions and inform ourselves, we will have drastic situations in the future.

In this sense, there has been a clear advance in technologies that improve water treatment, returning it under better conditions for its use in agriculture. It is also necessary to improve and improve techniques and technologies to ensure their usability for human consumption, in view of the water crisis experienced in recent decades.

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