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VALORIZATION OF WATER TREATMENT SLUDGE FROM A CIRCULAR ECONOMY PERSPECTIVE - THE CASE OF THE WTP OF AREIAS DE VILAR

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ABSTRACT
The water treatment process generates waste called Water Treatment "sludge" (WTS), which has added value and is therefore viable for use in other production processes, thus applying the principle of circular economy. This paper aims to present the results of the diagnosis of the Water Treatment Plant (WTP) of Areias de Vilar, Portugal. The WTP treats raw surface water (abstracted from river Cávado) by treatment scheme composed of the following unit processes: pre-oxidation, remineralization, coagulation/flocculation, decantation, fast filtration, disinfection and pH correction. In 2022, this plant produced more than 29 million m^3 of treated water and generated about 928 ton of sludge. After drying, a significant part of these sludges consists of silica (SiO_2), alumina (Al_2O_3) and hematite (Fe_2O_3), in addition to organic matter, aluminium hydroxide ($Al(OH)_3$), other oxidized metals, including calcium oxide (CaO) (mainly originated in the remineralization step), activated carbon and polyelectrolyte. The Areias de Vilar WTP has implemented a more efficient drying process (natural oven), to obtain a dry solid waste with more suitable characteristics for its recovery as a raw material in the construction industry, promoting a more sustainable approach from the perspective of the circular economy.

Keywords: Water treatment sludge, waste valorization, sustainability, circular economy.

INTRODUCTION
The production of drinking and industrial water generates waste, known as "sludge" from Water Treatment Plant (WTS). Most commonly WTS final destination is the landfill, with several potencial negative impact to the environment. So the search for sustainable alternatives for the treatment and reuse of WTS has been increased by the water industries and a new challenge for researchers worldwide. As the world's population increases, water consumption is expected to double by 2050 [1], and consequently a greater volume of sludge will also be produced, which is estimated at over 10,000 ton per day at global scale [2]. Among the several alternatives for its valorization is its use as raw material in other productive processes, thus applying the principle of circular economy. This practice will contribute to minimize the problems of scarcity of natural resources and may also generate new business opportunities for industry. Therefore, many treatment water utilities already adopt this sustainable management strategy by the recycling and reuse of this material [3].
Silica (SiO_2), alumina (Al_2O_3) and hematite (Fe_2O_3), usually represent a significant part of sludge. But, other oxides, chlorides (Cl^-), sulfates (SO_4^{2-}) and organic compounds are also in its composition. When aluminum salt coagulants are used, the waste generated is known as "alum sludge" [3]. Dried sludges have an highest aluminum content, his recovery (reaching 70-90%, using alkaline process) become a relevant environmental issue, and a sustainable alternative for WTS valorization [4]. The WTS present potential for application in several areas. In the construction sector, mortars produced with sludge as a replacement for Portland cement have confirmed their potential for use in the

production of blended and pozzolanic Portland cement [5]. The utilization of sludge for the production of supplementary cementitious material is considered as a viable and sustainable alternative [6]. Repair mortar produced with sludge replacing fine sand resulted in a mixture that provided more protection for steel reinforcement in aggressive environments with CO_2 and Cl^- [7]. Alum sludge has already been used as an adsorbent for phosphorus removal in wastewater [8] and to remove emerging pollutants found in water (steroid hormones 17β-estradiol and 17 β-ethinylestradiol) [9]. In the context of the circular economy, it follows that this waste can be recovered in various sectors. But, whatever the form of utilization, it is necessary to identify the quantitative and qualitative characteristics of the sludge that will be reused. This work aims to present the results of the diagnosis carried out at the WTP of Areias de Vilar, Portugal, in relation to the treatment phases and the residues generated in the process. This activity is part of the first phase of the PhD research in Waste Management and Treatment, which aims to evaluate the feasibility of reusing the sludge generated by this system in the construction industry.

METHODOLOGY OF RESEARCH

The study included bibliographic research, field activities and data collection. The bibliographic research, to know studies already carried out in the area; and the field activities, to verify in loco the stages of the treatment process employed in the WTP and how they can influence the composition of the sludge. The WTP data disclosed in this work were provided by Águas do Norte, S.A., the concessionaire responsible for the management of the Areias de Vilar WTP.

RESULTS AND DISCUSSION

The Areias de Vilar WTP treats surface water. The catchment is made in the river Cávado, downstream of the reservoir of the hydroelectric plant of Penide, in the municipality of Barcelos. The treatment steps (liquid phase) and the chemicals applied in the process are listed in Table 1**.**

Table 1. Treatment steps and chemicals applied at Areias de Vilar WTP.

Treatment step	Chemical product applied
Pre-oxidation	Ozone - O_3
Remineralization	Lime milk – $Ca(OH)_2$
	Carbon dioxide - CO_2
Coagulation/flocculation	Aluminum chloride hydroxide sulfate - $Al(OH)_aCl_{(3a-b)}(SO_4)_b$
	Powdered activated carbon
	Polyelectrolyte
Disinfection	Chlorine – Cl_2
pH adjustment	Lime water - $Ca(OH)_2$

The sludge is accumulated mainly in the decanters; to a lesser extent in the filtration units; and to an even lesser extent in the preparation tanks for the chemicals used in the process. The filter wash waters are fully recycled to the coagulation stage, while the sludge from the decanters is directed to the waste treatment line (solid phase), where it will be dewatered. The waste from the lime milk preparation tanks is also directed to the solid line. The plant uses an oxidant in the first stage of treatment, and impurities such as oxidized metals, essentially iron and manganese in insoluble form (Fe^{3+} and Mn^{4+}), will appear as residue. The solid fraction will also have $Al(OH)_3$, associated with the use of an aluminum salt as a coagulant; and it may contain a large amount of CaO, mainly because the lime sludge residues join the sludge from the decanters. Activated carbon and polyelectrolyte will also be present as a residue in the sludge. In 2022, the Areias de Vilar WTP produced more than 29 million m^3 of treated water, generating in that period about 928 ton of sludge, with an average humidity of 80% by weight. Dehydration is carried out in two stages: in centrifuges, obtaining in sludge with an average dry material content of 21%; and then in a natural thermal drying oven, where the final drying process takes place. The latter treatment unit was recently implemented and is currently being tested. An experimental drying cycle lasting 32 days obtained a residue with a dry material content of 70%.

CONCLUSIONS

WTP sludge is a process discharge, but with added value, which can be used in other production processes. At the Areias de Vilar WTP, with the implementation of the natural thermal drying oven for the treatment of sludge, it is intended to achieve a more efficient and less costly dehydration process, obtaining a material with physicochemical characteristics that expand its opportunities for valorization in the industry. The main goal of Águas do Norte, S.A. is to promote the declassification of this waste, with authorization from the Portuguese Environmental Agency - APA, for marketing as a raw material for the construction industry, namely for application in concrete products. However, to ensure efficient utilization, laboratorial analyses must be carried out to determine the major physical and chemical characteristics of these specific dry sludges, in oder to idenfify the suitable WTS valorization alternatives.

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References

[1] J. Baillie and Y. P. Zhang, “Space for nature”, *Science*, vol. 361, no. 6407. American Association for the Advancement of Science, p. 1051, Sep. 14, 2018. doi: 10.1126/science.aau1397.

[2] T. Ahmad, K. Ahmad, and M. Alam, “Sludge quantification at water treatment plant and its management scenario”, *Environ Monit Assess*, vol. 189, no. 9, p. 453, 2017, doi: 10.1007/s10661-017-6166-1.

[3] M. D. Nguyen, M. Thomas, A. Surapaneni, E. M. Moon, and N. A. Milne, “Beneficial reuse of water treatment sludge in the context of circular economy”, *Environ Technol Innov*, vol. 28, p. 102651, 2022, doi: https://doi.org/10.1016/j.eti.2022.102651.

[4] Boaventura, Rui A. R; Duarte, António A. L. S.; Almeida, Manuel F., “Aluminum recovery from water treatment sludges”, *Proceedings of IV International Conference on Water Supply and Water Quality*, Kraków, Poland, september, 11-13, IWA Publishing (CD-Rom), 2000. (https://hdl.handle.net/1822/5906)

[5] L. G. G. de Godoy, A. B. Rohden, M. R. Garcez, S. Da Dalt, and L. Bonan Gomes, “Production of supplementary cementitious material as a sustainable management strategy for water treatment sludge waste”, *Case Studies in Construction Materials*, vol. 12, p. e00329, Jun. 2020, doi: 10.1016/J.CSCM.2020.E00329.

[6] A. S. Ruviaro, L. Silvestro, T. P. Scolaro, P. R. de Matos, and F. Pelisser, “Use of calcined water treatment plant sludge for sustainable cementitious composites production”, *J Clean Prod*, vol. 327, p. 129484, 2021, doi: https://doi.org/10.1016/j.jclepro.2021.129484.

[7] T. A. Hemkemeier, F. C. R. Almeida, A. Sales, and A. J. Klemm, “Repair mortars with water treatment plant sludge (WTPS) and sugarcane bagasse ash sand (SBAS) for more eco-efficient and durable constructions”, *J Clean Prod*, vol. 386, p. 135750, 2023, doi: https://doi.org/10.1016/j.jclepro.2022.135750.

[8] N. Muisa, I. Nhapi, W. Ruziwa, and M. M. Manyuchi, “Utilization of alum sludge as adsorbent for phosphorus removal in municipal wastewater: A review”, *Journal of Water Process Engineering*, vol. 35, p. 101187, 2020, Accessed: Jul. 17, 2023. [Online]. Available: https://doi.org/10.1016/j.jwpe.2020.101187

[9] R. Dias *et al.*, “Study of the potential of water treatment Sludges in the removal of emerging pollutants”, *Molecules*, vol. 26, no. 4, 2021, doi: 10.3390/molecules26041010.