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Evaluating the accumulation rates of residual sludge and the possibility of their agricultural valorization in a Saharan context: The aerated lagoon wastewater treatment plant at the Ouargla Oasis (Algerian south-east)

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Abstract

Background: This study aimed to assess the accumulation rates and potential agricultural value of residual sludge from the aerated lagoon wastewater treatment plant in Ouargla province, which has long faced issues of rising and pollution of ground water. The plant was constructed in 2009 to mitigate these problems. After more than a decade of operation, it is essential to determine the management strategies for the sludge accumulated in the basins to prevent harmful consequences on both the purification process and the environment.

Methods: To achieve this objective, we measured the thickness of the sludge accumulated at the bottom of the lagoon basins and estimated the total sludge volume in each basin. In addition to these quantitative measurements, sludge samples were collected from the basins and a series of physicochemical and bacteriological analyses were conducted.

Results: The results highlight the heterogeneous spatial distribution of sediments in the studied basins. Based on the average height of the accumulated sludge, dredging is necessary for basins F2, A3, and B2. The average annual accumulation rate calculated for the entire wastewater treatment plant is 30.95 cm/year. The sludge produced by this plant is dry and has low fermentability when stored. It contains 2.58% nitrogen and 0.55% phosphorus on a dry matter (DM) basis, with very low concentrations of heavy metals.

Conclusion: This sludge can help increase agricultural soil's nitrogen, phosphorus, and potassium content. It appears to be safe regarding the following trace metals: copper, nickel, cadmium, mercury, lead, and zinc.

Keywords: Sewage, Water purification, Lagoons, Fertilizers, Heavy metals

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Introduction

According to the study by Carpier et al (1), aerated lagooning is characterized using treatment ponds where the biodegradable load of an effluent is broken down through bacterial action. At least a part of this treatment is carried out aerobically by artificially introducing dissolved oxygen into the water via mechanical aeration, air blowing, or other methods.

One consequence of this process is the production of residual sludge, which consists of undegraded organic matter, mineral matter, microorganisms, and water (approximately 99%) (2). Dredging of lagoon sludge is an essential step to maintain a high level of wastewater treatment before its discharge into the receiving environment. This is a major and demanding operation from a technical, regulatory, and budgetary stand point. In practice, the initiation of the dredging operation must be preceded by observations, measurements, and diagnostics to assess its appropriateness. This sludge contains significant amounts of nutrients that agricultural crops can effectively utilize (1).

When their use of sludge for agriculture is permitted, it must comply with local legislation. The refusal to reuse it in agriculture is often due to limiting factors such as high concentrations of heavy metals, the presence of pathogens and their attraction to biological vectors, as well as the presence of toxic organic compounds (3).

In Algeria, the increase in the number of wastewater treatment plants has led to a growing production of sewage sludge. Evacuating this sludge to technical landfill sites is not a sustainable long-term solution, highlighting the importance of valorizing it through reuse for agricultural purposes (4). Ouargla is a province located in the Algerian Sahara, approximately 850 km southeast of the capital, Algiers. It is characterized by a hot and highly evaporative climate, with annual evaporation exceeding 300mm in some years (5) and has long faced issues of high groundwater levels and pollution. To alleviate these problems, the aerated lagoon wastewater treatment plant was established in 2009. Since this year, numerous studies have been conducted to analyze the quality of wastewater and treated water from this treatment plant and their reuse in agriculture. The most important is the study conducted by Mensous (6), Ounoki and Achour (7), Bouhanna (8), and Negais et al (9). Furthermore, many studies have also been conducted to explore the possibility of tertiary treatment of the plant water, as carried out by Khacheba et al (10). No study has been conducted on the quantity, quality, and management of the sludge at this station, even though more than 12 years have passed since sludge began accumulating in the lagoons.

The first aim of this study was to assess the distribution and accumulation rate of sludge produced by the urban wastewater treatment plant in Ouargla, Southeast Algeria. Measurements were taken after 14 years of system operation without any maintenance. The accumulation and distribution rates of sludge were determined by measuring the thickness of the sludge layer at various locations within each lagoon. This is the most commonly used method for estimating sludge accumulation, typically expressed as an empirical accumulation rate in terms of volume per capita. The second objective of the study was to identify the lagoons that require sludge removal. Additionally, the present study aimed to analyze the physical, chemical, and biological properties of the accumulated sludge to assess its potential for agricultural valorization.

Materials and Methods

The studied plant is located in the northeast of the Ouargla agglomeration, approximately 10 kilometers from the city center (Figure 1).

It is specifically designed to handle liquid waste from the urban areas of the Ouargla agglomeration until 2030. The station is composed of the following elements:

- Lifting and pretreatment of raw effluents, including a lifting, screening, and sand removal station.
- Stage 1 of the aerated lagoon, consisting of lagoons A1, A2, A3, and A4, with a depth of 3.5 m.
- Stage 2 of the aerated lagoon, consisting of lagoons B1 and B2, with a depth of 2.8 m.
- The finishing lagoons, F1 and F2, each with a depth of 1.5 m.
- A drying bed for sludge treatment.

The lagoons occupy a surface area of approximately 60 hectares, while the sludge-drying beds cover around 10 hectares.

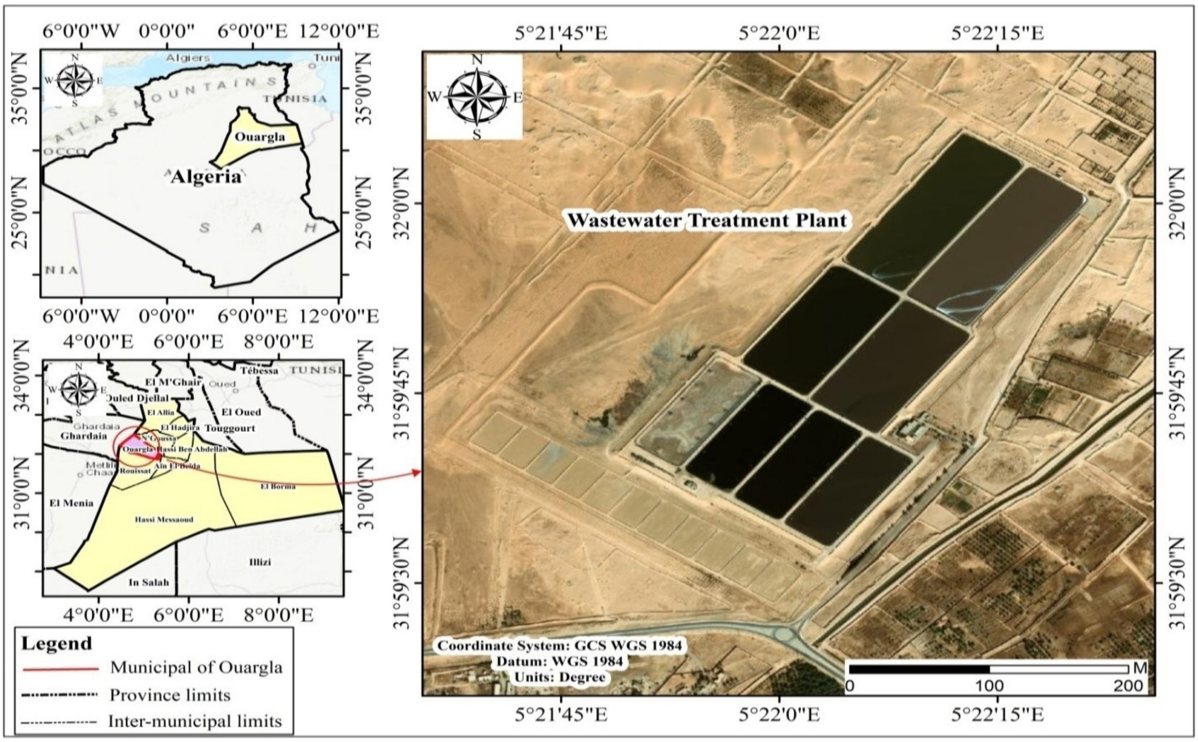

Figure 1. Status of the Ouargla wastewater treatment plant

The aerated lagooning technique involves biologically treating the effluent by introducing artificial oxygen. The lagoons facilitate the decomposition of organic matter, measured by the BOD_5 parameter, through the action of microorganisms (11).

The treated wastewater from this station is discharged to an evaporation site located about 40 kilometers north of the plant.

The Ouargla wastewater treatment plant was commissioned in 2009 with a total capacity of 400,000 EH (12). Since its simple mentation, sludge from wastewater treatment has accumulated in the lagoon basins, increasing their volume overtime. Recently, efforts have been made to clear the basins and dry the sludge for characterization.

Measurement of sediment thickness and accumulation

Based on the treatment stage and the operating duration of each basin, we selected six of the eight existing basins for the study: A2, A3, B1, B2, F1, and F2.

The sediment thicknesses were measured directly using a pole, following a 10-meter grid established over each basin. This technique is adapted from the work of CEMAGREF and was later modified by the "Sanitation and Environment" unit of the Department of Environmental Science and Management at the University of Liège (13). The sediment thickness was determined by subtracting the depth of the water column, measured using a sliding rod equipped with a porous disk at its lower end, from the total bas in depth, measured using a main rod. The sliding rod descended along the main rod until it reached the surface of the sediments, and the difference between the two measurements determined the thickness of the sediment layer.

The measurement of sediment thickness was carried out between December 25, 2022 and February 25, 2023.

The three-dimensional surface profiles were reconstructed using Surfer version 19, and the total sludge volume in each basin was estimated using the same software. This volume was calculated by integrating the surface area of the sediments using Simpson's 3/8 Rule.

The annual accumulation rate, expressed in cm/year, is the ratio of the total volume of sludge to the surface area of the basin, divided by the number of years or months of operation. The accumulation rate, expressed in m^3/EH/year, is calculated as the ratio of the total sludge volume (Vs) for each basin (estimated using the Surfer software) to the number of equivalent in habitants, divided by the number of months of operation.

Sampling and physicochemical characterization of sediments

Sediments were collected from basins A3, B2, and F2, which contained the most sludge at each stage of the lagoon system. Samples were taken at the inlet, middle, and outlet of each basin.

Throughout our study, the dredger used for mechanical sludge extraction was out of order, so manual sampling was performed using a wooden pole with a clean bucket. Nine sludge samples were collected and immediately sent to the drying bed. After on month of drying, the samples were transported to the laboratory in tightly sealed jars for the necessary analyses. Sludge transportation, drying, and storage followed ISO5667-1 (14) requirements.

The examined sludge is of biological origin, consisting of solid gray aggregates with a slight unpleasant odor, resulting from the fermentation of organic matter at the bottom of the lagoons. The samples were ground and sieved using a 2 mm sieve to prepare them for analysis of the following parameters: pH and electrical conductivity (EC), which were measured in an aqueous medium, following the analysis protocol outlined by the Center of Expertise in Environmental Analysis of Quebec (15,16); dry matter (DM) and suspended volatile matter (SVM), which were measured using the techniques described by Rejsek (17) for water analysis (DM after drying at 105 °C and SVM after combustion at 525 °C).

Regarding nutrients, total nitrogen (TN) was determined using the Kjeldahl method (18), and total phosphorus (TP) was measured using the ISO 11885 technique (19). Total calcium (expressed as CaO) was determined by NA 1655 (20), total magnesium (as MgO) was determined by NA 752 (21), and total potassium (asK_2O) by NA 1653 (22). For trace metal elements (Co, Ni, Cd, Hg, Pb, and Zn), detection and quantification were carried out using ISO 11885 methods (23). Fecal coliforms (FC) and fecal streptococci were analyzed in compliance with the French standard NFENISO 9308-1 (24). Data were analyzed using XLSTAT version 2021.5. We conducted an economic study to apply the results by creating a productive project that also preserves the environment. By calculating the amount of nutrients present in the studied sludge and determining the final fertilizer quantity based on a target NPK formula of 11-25-25, we assessed the associated costs and potential benefits.

Results

Sludge accumulation

The distribution of sediments in the two aerated lagoon basins of the first stage, A2 and A3, with a depth of 3.5 m, was heterogeneous. The sediment thickness in basin A2 ranged from 0.01 to 0.8 m, while in basin A3, it ranged from 0.15 to 0.99 m (Figure 2). This variation in sediment thickness between the two basins is due to differences in their operating durations (Table 1). The maximum sediment thickness was recorded at the inlet of both basins, but in basin A2, two cumulative cones were formed on the right and left sides, while in basin A3, they accumulated in to a single mass.

Basins B1 and B2, located in the second stage of the aerated lagoon at a depth of 2.8 m, exhibited unique sediment distribution patterns. Basin B1 showed anon-homogeneous distribution, while basin B2 was nearly homogeneous (Figure 3). Sediment thickness in basin B1 ranged from 0.01 to 0.15 m, while in basin B2, it varied from 0.01 to 0.74 m. The significant variation in thickness at the same stage is because basin B1 experienced fewer months of operation compared to B2 (Table 1). The volume of treated water in basin B1 represented one-third of that treated in basin B2, resulting in a sludge accumulation in basin B2 similar to that in the first-stage basins.

Except for the left side of the basin entrance, where sediments gathered in a cone in the corner, the sediments in basin B1were distributed as a very thin layer covering the entire bottom. In contrast, sediments in basin B2 were more homogeneously distributed, forming a layer approximately 0.4 m thick across the bottom, with some areas where it accumulated in ridges exceeding 0.6 m. The heterogeneous spatial distribution of sediments in the first- and second-stage lagoons can largely be attributed to the automatic aeration process during water treatment, which uses surface aerators. In the third-stage basins, known as "decantation lagoons" by Ministry of Environment and Quality of Life (MECV) and the Ministry of Agriculture (MDV) (25), sediment distribution resulted from the

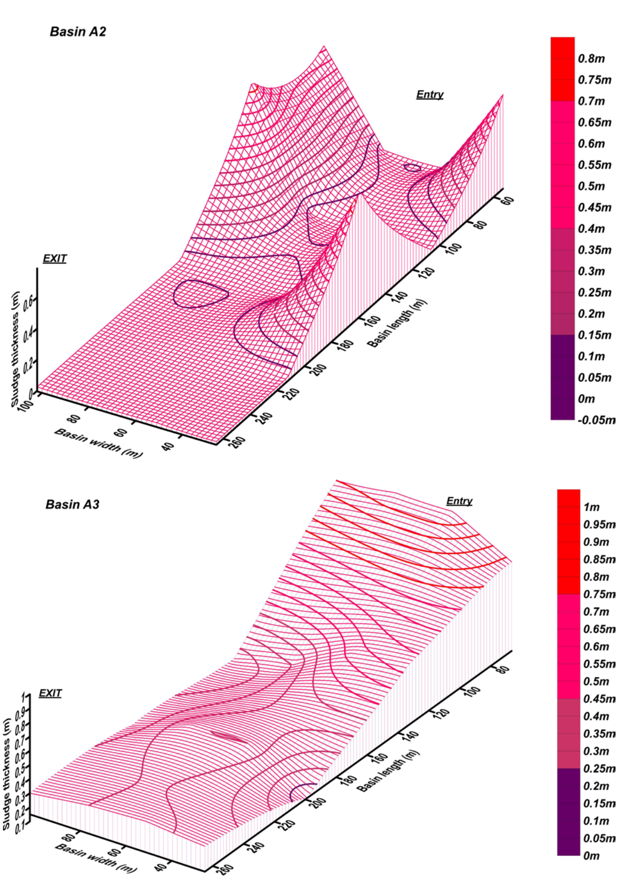

Figure 2. Spatial distribution of sediments in the two basins of the first floor of the aerated lagoon: A2 and A3

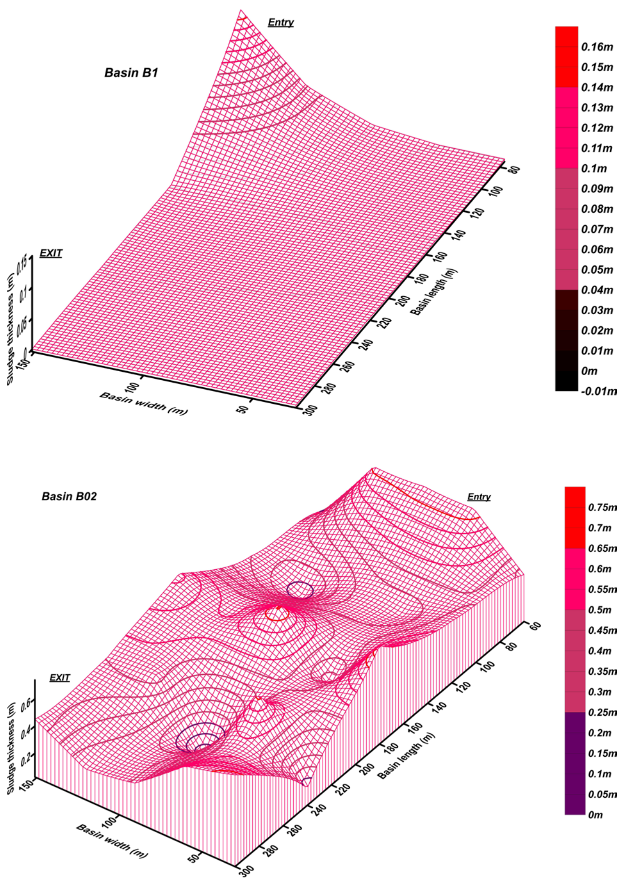

Figure 3. Spatial distribution of sediments in the two basins of the second floor of the aerated lagoon: B1 and B2

Table 1. Sludge production in each basin

Basins	Number of operating months	Sediment's thickness			Net volume (m³)	Total volume (m³)	Filling rate (%)	Accumulation rate	
		Min (cm)	Max (cm)	Average (cm)				cm/year	m³/EP/year
A2	72	1.31	81	15.2	1959.11	85 200	2.299	2.53	/[a]
A3	168	15	100	49.4	7053.78	85 200	8.279	3.52	/[a]
B1	72	1	15	7	189.38	113 600	0.166	1.66	/[a]
B2	168	1.15	75	44.7	12655.75	113 600	11.14	79.86	/[a]
F1	72	0.01	0.09	0.04	12.02	74 027	0.016	0.13	/[a]
F2	168	49	95	67.9	19813.37	74 027	26.748	98	/[a]
Total	/[a]				41683.41	460 454	/	30.95	0.015

Note. Vt: Total volume of each basin; Vnet: Sediment volume calculated by Surfer software; EP: Equivalent population.
[a]The slash mark indicates that this box is not relevant to the calculation, meaning it cannot be estimated.

physical separation of settle able materials, which formed the sludge from purified water.

The two finishing basins, F1and F2, with a depth of 1.5 m, also exhibited heterogeneous sediment distribution. In basin F1, sediment thickness ranged from 0.0001 to 0.0009 m, while in basin F2, thickness varied from 0.49 to 0.94 m (Figure 4). The significant difference between the two basins is due to the variation in their operating months. In basin F1, the settled sediments formed a highly variable layer, with area so fin creased thickness appearing in cone-like formations. The maximum sediment thickness in basin F2 was recorded on the right side of the basin entrance.

Sludge production

The net volume, filling rate, and sediment accumulation rate were measured in the six studied basins to assess sludge production at the Ouargla wastewater treatment plant. The results are presented in Table 1. The table shows an increase in sediment volume from the first-stage lagooning basins to the final-stage basins, with variations between basins at the same level. The volume recorded was 7053.78 m^3 in basin A3, 12655.75 m^3 in basin B2, and 19813.37 m^3 in basin F2. This increase is due to the processes occurring at each lagoon treatment level. According to the study by Berland et al (26), in the aeration basins at levels 1 and 2, the water is treated by microorganisms that consume and assimilate nutrients from the pollutants to be eliminated. This biological activity transforms pollutants, and the degradation of organic matter is accompanied by the sedimentation of settle able materials in the effluent. In the settling stage, suspended matter, including clusters of microorganisms and trapped particles, settles to form sludge in the finishing basins.

Based on the sediment filling rates, the volume of sludge in basins A2, A3, B1, B2, and F1 is relatively low compared to the total volume of the basins, ranging from 0.016% to 11.14%, which is below the 25% threshold, at which, dredging becomes necessary (27). In contrast, sludge in basin F2 occupies 26.74% of the total volume, making dredging essential for this basin.

Referring to the average sludge height criterion used to initiate dredging, Racault and Boutin (28) demonstrated that when the sludge height exceeds 25 cm, dredging is systematically required. Accordingly, dredging is necessary for basins A3, B2, and F2, where the average sludge heights are 49.4, 44.7, and 67.9 cm, respectively.

The annual accumulation rates range from 0.13 to 98 cm per year. The annual rates for basins A2, A3, B1, B2, F1, and F2 are 2.53, 3.52, 1.66, 79.86, 0.13, and 98 cm/year, respectively. The average accumulation rate for the entire station is 30.95 cm/year.

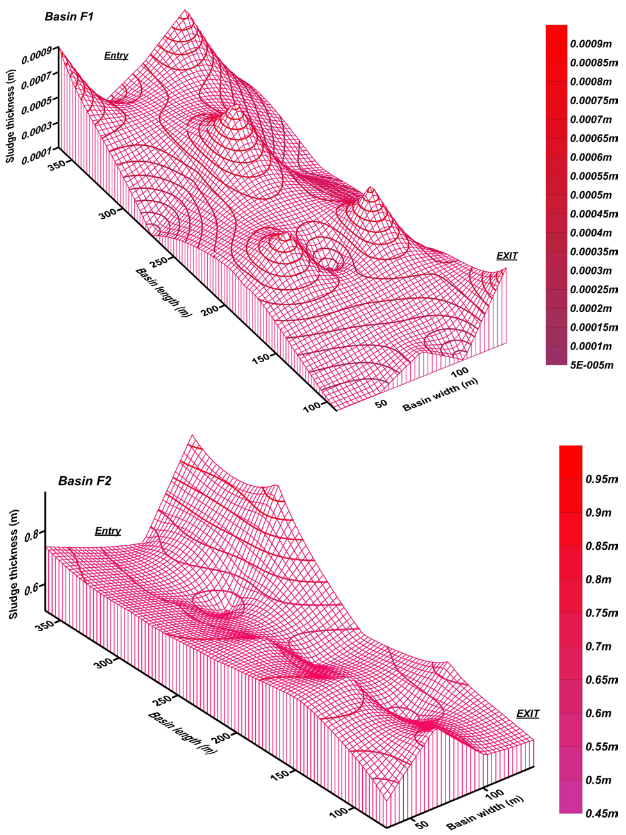

Figure 4. Spatial distribution of sediments in the two finishing basins: F1 and F2

Sediment characterization

Physicochemical characterization

The data presented in Table 2 includes the pH levels, EC, dryness, and suspended volatile materials in the sludge, measured at the inlet, middle, and outlet of basins A3, B2, and F2. On this basis, the sludge was determined to have an average pH of 7.54, classifying it as alkaline, and an average EC of 9.390 µS/cm, indicating that it is saline. The quasi-homogeneity of alkalinity and salinity in the sludge across the three basins is evident due to the low standard deviation values observed for both variables. The elevated EC values are directly linked to the wastewater's high conductivity, which contributes to the formation of settled sludge. The EC of raw water was 24000 µS/cm, and that of

Table 2. Characteristics of the sludge in basins A3, B2, and F2, pH, EC, dry matter (DM), suspension volatile materials (SVM), andfertilizer element (total nitrogen (TN), total phosphorus (TP), potassium (k), magnesium (Mg) and total calcium (Ca))

n=9	pH	EC (µS/cm)	DM (%)	SVM (%)	TN (%)	TP (% of DM)	K (% of DM)	Mg (% of DM)	Ca (% of DM)
Mean	7.54	9390	96.73	19.67	1.16	1.28	0.56	6.04	1.35
Standard deviation	0.76	195	1.43	9.59	0.18	0.7	0.03	0.79	0.17

treated water was 14000 µS/cm, according to the Ouargla wastewater treatment plant (WWTP) (29).

Given the pH and EC of this sludge, it is essential to know the soil characteristics–particularly pH and EC–before applying the sludge to the soil to mitigate the risk of increased salinity and alkalinity.

It is also evident that the sludge generated by the three studied basins exhibits extremely high dryness, with values exceeding 96%. The low variability in the dryness of the sludge across the three basins is confirmed by the low standard deviation (1.43). This is illustrated in more detail in Figure 5, where the DM content in the sludge varies laterally between 96% and 98%, while it reaches 93% at the inlet of basin B2. According to a study by Keffala et al (13), which assesses sludge consistency based on its dryness, the sludge from the Ouargla WWTP is classified as dry. The high consistency can be attributed to the effectiveness of the solar drying process used at the plant.

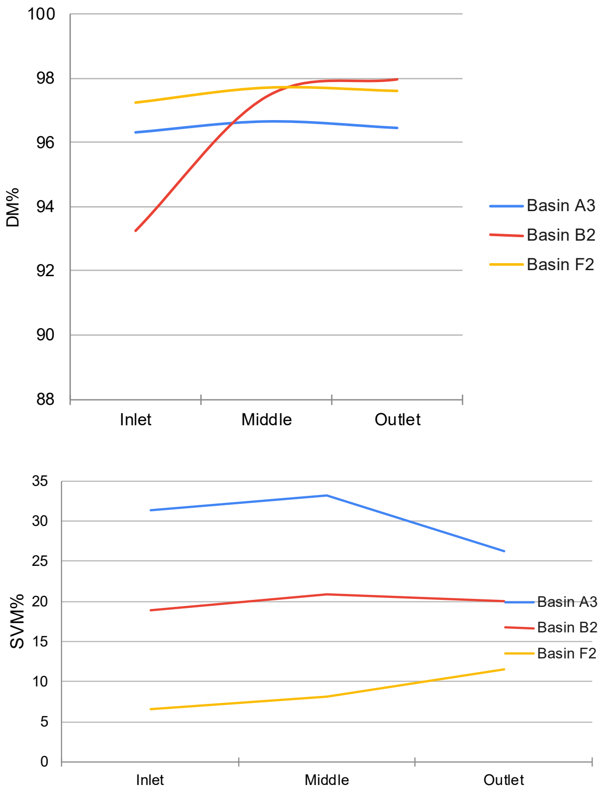

Figure 5. Lateral distribution of dry matter (DM) and suspension volatile materials (SVM) contents in basins A3, B2, and F2

The average percentage of SVM in the sludge from the three basins is 19.97%. Given the standard deviation of 9.59, the measured values show significant variation around the mean. As shown in Figure 5, the highest values were observed at the first lagoon treatment stage, exceeding 30%. At the second stage, they dropped to 20%, and at the final lagoon stage, they reached 9%. According to the study by Rejsek (17), the se low values suggest that the dry sludge produced by the Ouargla wastewater treatment plant is not easily fermentable. This can be attributed to the aeration process during drying, where aerobic microorganisms break down the organic matter present in the sludge. This process, known as aerobic gestation, is used to stabilize the sludge.

Nutriments

The primary fertilizing elements (N, P, K, Mg, and Ca) constitute only 10.39% of the sludge's DM. Magnesium is the most abundant element, accounting for 6.04%, while the other elements have concentrations below1.5% (Table 2). The wastewater from the Ouargla province, which is the source of the studied sludge, is classified as saline wastewater (9,29-31). The increased osmotic pressure from saline ions in the water poses a significant threat to the microorganisms responsible for biological treatment, severely limiting the efficiency of the wastewater treatment process (32-34). Consequently, the composition of the sludge deposited during treatment is directly affected.

Trace metal elements

According to Table 3, the presence of heavy metals in the sludge is low, found in trace amount sand well below the maximum allow able concentrations specified in the Algerian standard (NA17731:2017) and AFNOR (U44-041:1985) for the agricultural use of sewage sludge (4,35). This significantly reduces the risk of soil contamination and prevents the transfer of trace metal elements in to cultivated plants or their vertical migration in to aquifers.

Table 3. Trace metal elements content in sludge in basin B2

Element	Concentration (mg/kg of dry matter)	Algerian standard (NA17731:2017) (mg/kg of dry matter)*	AFNOR standard (U44-041:1985) (mg/kg of dry matter)
Co	0.072	1750	2000
Ni	0.00	400	400
Cd	0.05	40	40
Hg	0.001	25	20
Pb	0.05	1200	1600
Zn	0.05	4000	6000

Copper (Co), Nickel (Ni), Cadmium (Cd), Mercury (Hg), Lead (Pb), and Zinc (Zn).
*No sludge content in any of these trace elements should exceed 25% of the corresponding maximum content.

The low concentration of trace metal element sin the sludge can be attributed to its treatment of predominantly house hold wastewater, which is rich in organic matter, as opposed to industrial wastewater, which is higher in minerals.

Bacteriological characterization

The results of the bacteriological analyses, presented in Table 4, show that the sludge from the Ouargla wastewater treatment plant contains neither FC nor fecal streptococci. The absence of fecal contamination in the sludge can be attributed to its high salinity. Sun exposure also plays a crucial role in reducing bacterial abundance, especially in conditions of elevated pH.

Economic study

Quantity of nutrients in the sludge

- Annual quantity of sludge: 5100 cubic meters = 10200 tons (assuming sludge density of 2 tons/cubic meter).
- Amount of nitrogen in the sludge: 10200 tons × 1.16% = 118.32 tons.
- Amount of phosphorus in the sludge: 10.200 tons × 1.28% = 130.56 tons.
- Amount of potassium in the sludge: 10.200 tons × 0.56% = 57.12 tons.

Final quantity of fertilizer

To produce a chemical fertilizer (NPK), we need to combine the nutrients extracted from the sludge with other ingredients to achieve the target formulation:

- Nitrogen (11%)
- Phosphorus (25%)
- Potassium (20%)

Based on the available quantities s of nutrients from the sludge, we can estimate the amount of NPK fertilizer that can be produced.

Available quantities of nutrients:

- Available nitrogen: 118.32 tons
- Available phosphorus: 130.56 tons
- Available potassium: 57.12 tons

Potential final quantity of fertilizer

We use the smallest available amount of nutrients to determine the total amount of fertilizer that can be produced. Potassium is the limiting element (smallest quantity):

- If potassium represents 20% of the fertilizer, the total amount of fertilizer that can be produced is calculated as:

Total finished fertilizer that can be produced = 57.12 tons/ 20% = 285.60 tons of finished fertilizer (NPK).

Thus, the total potential amount of finished fertilizer (NPK) that can be produced is 285.60 tons.

From Table 5:

Labor: This process requires three workers. The monthly labor cost is 60000.00 DZD, which means the annual wage cost is 720000.00 DZD.

Consumed bags: The production process requires 5800 bags, with the current market cost of one bag estimated at 30 DZD, which means the annual cost of the bags is approximately 174000.00 DZD.

Discussion

The results of the bathymetric, physicochemical, and bacteriological analyses of the residual sludge produced by aerated lagooning in the basins of the Ouargla wastewater treatment plant indicate that the sedimentation pattern observed in basins A2, B2, F1, and F2 is consistent with the results of studies on lagooning conducted by Racault in France (36), where he demonstrated an irregular accumulation of deposits in the basins. Depending on the basin's shape, the deposits are more concentrated in three areas: the entrance, the exit, and a long a lateral strip. In these regions, where flow rates are slower, sedimentation is more significant. However, the scenario out lined by Vuillot and Boutin (37), which suggests that most sludge settles near the wastewater in flow, forming a sedimentation cone, is consistent with the sedimentation pattern in basins A3 and B1. The remaining portion evenly settles at the lagoon's bottom.

The average sludge accumulation rate is lower than that of the sludge accumulated in a wastewater stabilization system in Vamvakofito (Northern Greece), with a rate of 0.09 m^3/person/year compared to 0.015 m^3/equivalent in habitants (EH)/year in our station. However, the opposite is observed when comparing the thickness of the sediments accumulated in the two stations: 30.95 cm/year in the Ouargla station and 1.4 cm/year in the Vamvakofito station (38). This disparity may be related to the treatment

Table 4. Results of the bacteriological analyses of the sludge in basins A3, B2, and F2

Parameter	A3	B2	F2
Fecal coliforms (CFU/mL)	Absent	Absent	Absent
Fecal streptococci (CFU/mL)	Absent	Absent	Absent

Table 5. Financial aspect

The statement	The quantity	The price	The total amount DA
Turn over.......1	285.60	8000.00	2284800.00
Used bags	5800	30.00	174000.00
Labor force	12	60000.00	720000.00
Wear and tear	12	30000.00	360000.00
Maintenance expenses, electricity, water...The (1%) of 1		228480.00	228480.00
The result			802320.00

capacity of each station.

The pH of the sludge from the wastewater treatment plant in Ouargla is similar to that of the sludge from the wastewater treatment plant in Fès (39) and complies with the standards of the French High Council of Public Hygiene (CSHPF). However, it is important to note that the sludge from Ouargla has a high salinity, as indicated by its EC, which poses a risk for agricultural use.

The dryness of the sludge produced by the Ouargla station is very high, similar to that of the dry sludge from the wastewater treatment plant in Touggourt (a city in the Algerian Sahara located 160 km from Ouargla) (40). According to the study by Gratziou and Chalatsi (41), high dryness has the advantage of reducing the volume of sludge to be transported and allows for its storage in the field, which is not permitted with liquid sludge. High dryness conditions also facilitate the transport of sludge to specialized composting sites. The sludge from the Ouargla plant has an organic matter content, expressed as suspended volatile solids, is moderately low and similar to that of the sludge from Touggourt that has a higher nitrogen content (2.6% in Ouargla sludge compared to 1.55% in Touggourt sludge), but their phosphorus contents are nearly equal (0.55% in Ouargla and 0.52% in Touggourt). With this composition, the application of sludge from the Touggourt station to agricultural soils-practically identical to those of Ouargla (42) led to improvements in soil characteristics, organic matter content, cation exchange capacity, and water retention capacity. Additionally, it has resulted in increased crop production. Therefore, the levels of fertilizing elements found in the studied sludge could also enhance soil quality and increase crop productivity under similar usage conditions.

In the sludge of the Ouargla station, the concentration of heavy metals (copper, zinc, nickel, and cadmium) was lower than the results from the sludge of the wastewater treatment plants in Mazandaran (43). However, in both cases, following the standards, the use of these bio solids in agriculture is not restricted to these metals.

Conclusion

The first aim of this study was to assess the distribution and accumulation rate of sludge produced by the aerated lagoon wastewater treatment plant in the Ouargla province, located in the southeast of Algeria, after 14 years of operation without maintenance. Sludge accumulation was measured by the thickness of the layer at different locations within the lagoons. The study also aimed to identify the lagoons that require sludge removal and to analyze their physical, chemical, and biological properties to evaluate their potential for agricultural use.

The findings indicate a heterogeneous spatial distribution of sediments, with variable thickness in the studied basins, typically the highest at the basin entrance. In lagoon F2, sludge comprises 26.74% of the total volume, necessitating dredging. Additionally, dredging is required in basins A3, B2, and F2, where average sludge heights exceed 25 cm. Annual accumulation rates vary from 0.13 to 98 cm/year. The average accumulation rate for the Ouargla station is 30.95 cm/year, equivalent to 0.015 m^3/EP/year.

The sludge produced at this station is dry, making solar drying the most effective treatment method due to favorable climatic conditions. It has low fermentability, containing 2.58% nitrogen and 0.55% phosphorus, which can enhance crop productivity. The sludge also has very low heavy metal concentrations, below the allowable limits of Algerian and AFNOR standards. Additionally, it is free from fecal contamination, including fecal streptococci and coliforms. However, they are salty.

It is recommended to establish more regular monitoring systems to anticipate dredging needs. Furthermore, conducting more studies on reducing sludge salinity is essential to prevent harmful effects on agricultural soils. Further studies on the long-term sustainability of agricultural sludge use are also necessary to assess its environmental impact. Finally, extending the study to other regions with similar climatic conditions would enable the generalization of these recommendations.

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Authors' contributions

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Data curation: Soumia Merabet and Tahar Idder.
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Competing interests

There are no conflicts of interest associated with this publication.

Ethical issues

The practical part of this work was carried out with the assistance of workers from the Ouargla Wastewater Treatment Plant, after approval of the mission issued by the plant director, Mr. Abdeslam Chettouh. No animals were used in this study.

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