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# Characterization of the Physical, Chemical, Organic and Biological Parameters of the Sewage Sludge from Sonfonia-conakry, Guinea

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**Abstract:** This study focuses on the evaluation of the ammonia ($NH_3$) stripping and the sizing of a sludge treatment plant, based on experimental results obtained at the station Sonfonia (Conakry, Guinea), based on the Heins-Coll model. The targeted physicochemical parameters are temperature, the pH and nitrogenous forms $NH_3/NH_4^+$. The nitrogen stripping process is described using the Azov and Goldman mathematical model, which allows for the estimation of the concentration of stripped ammonia nitrogen (N-$NH_3$) as a function of temperature and pH. The methodology is based on sampling the liquid fraction at different levels of the station, followed by physicochemical analyses and a comparative interpretation of the results. The average results obtained for the period 2022-2023 at the plant inlet are as follows: temperature of 29.71 °C, pH of 7.74, and $NH_3$ concentration of 28.76 mg/L. These values show that the ammonia load of the incoming sludge is significantly lower than that considered in the initial design of the plant (142 mg/L). Monitoring the flow of the effluent through the four lagoons reveals a progressive decrease in concentrations, with average values of 29.66°C and pH of 7.66. And $NH_3$ of 16.91 mg/L, reflecting a significant purification performance of the lagoon system. Nitrogen stripping tests were conducted in 2023 at Lagoon 1, based on six observation points. The application of the Azov and Goldman model yielded the following results**:** temperature of 32.15 °C, pH of 9.62**,** $NH_4^+$ of 37.82 mg/L, $NH_3$ of 29.83 mg/L, with an $NH_3/NH_4^+$ ratio of 78.78%, confirming the determining influence of pH and temperature on the effectiveness of ammonia stripping. In conclusion, the analysis of the treatment performance of the Sonfonia sludge treatment plant highlights the relevance and robustness of the Azov and Goldman mo**del**, combined with the Heins-Coll model, for understanding nitrogen stripping mechanisms. The results obtained provide a reliable scientific basis for the optimization and design of new sludge treatment plants adapted to tropical climatic conditions.

**Key words:** Sewage sludge, characterization, flow path, lagooning, stripping, Sonfonia.

## 1. Introduction

In most African countries, sanitation in general, and wastewater and excreta management in particular, are not always a priority. This situation is certainly one of the causes of the high rates of waterborne diseases observed in these countries [1]. On-site sanitation systems generate a large quantity of sludge that must be managed. Indeed, a study conducted by the United Nations Population Fund in 2006 revealed that the population in Africa and Asia will double between 2000 and 2030 [2]. With rapid population growth and improved access to sanitation, Africa will face an enormous amount of fecal sludge. On-site sanitation systems (latrines and septic tanks) require emptying after a certain period of use. Thus, to manage the by-products of sanitation from these structures, the population resorts to mechanical emptying and/or manual emptying which dumps the sludge in the streets, quarries, and even fields [3].

Septic tank sludge is sludge of varying consistency, collected from sanitation systems not connected to the sewer network: latrines, public toilets, septic tanks, and water closets. It is too rich in pollutants to be discharged into surface waters or treated as wastewater, too liquid to be landfilled or treated as solid waste. It is also too rich

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in pathogens to be used directly for soil fertilization [4].

These sludges, discharged into the natural environment, can cause nitrate pollution (nitrification-denitrification). This phenomenon is widespread in Africa, following percolation in wells and boreholes located near garbage dumps, latrines, and septic tanks [5]. Furthermore, nitrogen concentrations in sewage sludge can vary between 300 and 5,000 mg/L. This affects the growth of algae that play a role in the degradation of the pollutant load in facultative ponds [6]

Sonfonia treatment plant was built in 2001 by the World Bank, Canada, and the Guinean government to treat sewage sludge from the city of Conakry. It consists of three parallel sub-processing lines, each treating 50 $m^3$/day of sewage sludge, two-thirds of which comes from latrines and one-third from septic tanks. It is located in the Sonfonia-Gare district of the Ratoma municipality.

Is the Sonfonia sludge treatment plant efficient?

Sonfonia sludge treatment plant.

The sonfonia processing station includes

Two (2) sedimentation basins, with a volume of 155 $m^3$ and equipped with screens; three degassing lagoons, specifically dedicated to the reduction of ammonia nitrogen. These basins are designed based on atmospheric stripping; one anaerobic lagoon, with a volume of 615 $m^3$ and a sludge accumulation zone of 185 $m^3$.

The basins are subdivided into two compartments with a maximum depth of 3 m, and a retention time of 11 days. A sludge drying area is adjacent to them (Fig. 1).

The sewage sludge is screened and then settled in batch sedimentation basins. After a 30-day filling period, the basins are left to rest for another 30 days, after which the thickened sludge is removed by shovel. During the thickening period, incoming sewage sludge is transferred to another basin of the same dimensions. There will therefore be an alternation between a resting basin and a basin receiving sewage sludge. The supernatant from the sedimentation basins [7] then flows through a series of stripping basins, and subsequently into anaerobic treatment basins. The treated effluent is discharged into the Botari River and flows out to sea. A composting system for the dried sludge is planned.

The route of the Sonfonia station is illustrated in Fig. 1.

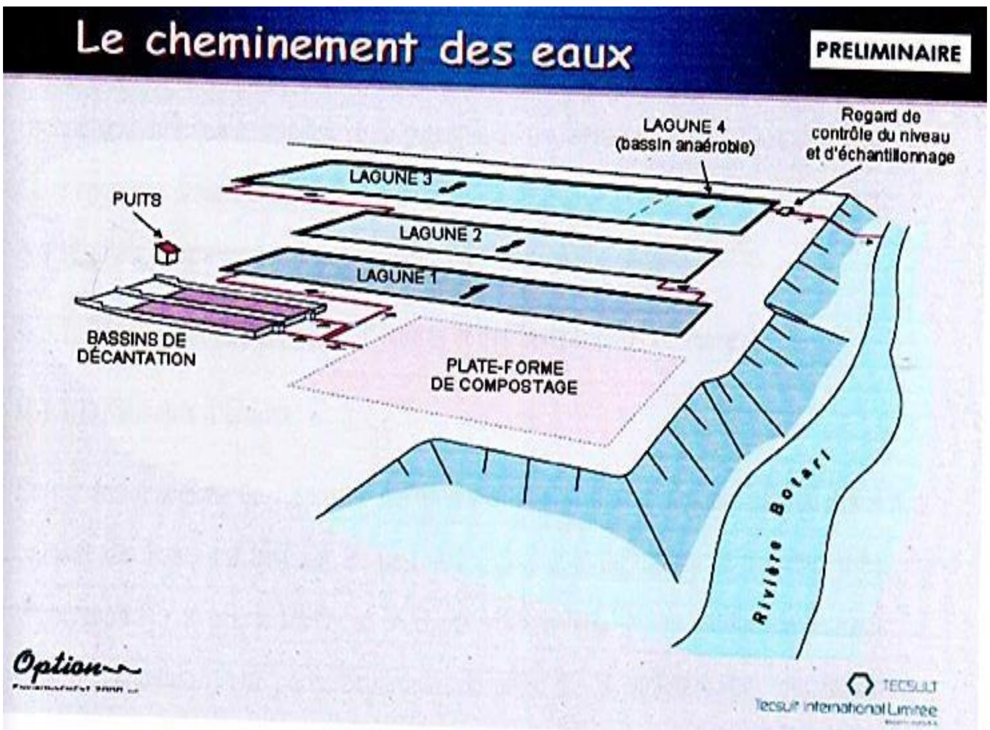



**Fig. 1 Overview of the Sonfonia station. Source [8].**

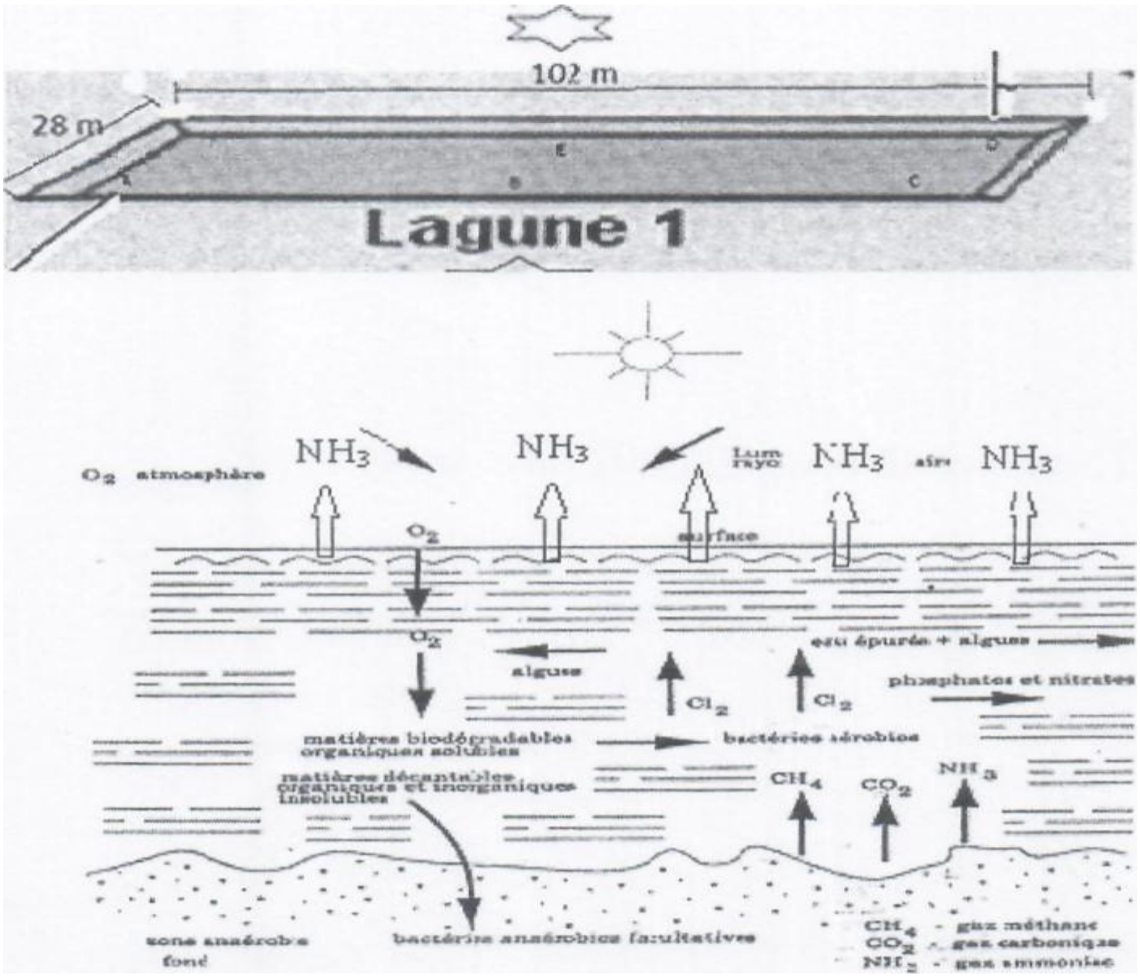



**Fig. 2 Presentation of the Diagram of the Stripping Process in Lagoon 1. Source [8].**

## 2. Methodology

The nitrogen stripping process is described by the mathematical model of Azov and Goldman, which allows the concentrations of stripped nitrogen N-$NH_3$ to be calculated as a function of temperature T and pH, [1].

$$NH_3 - N = NH_4^+ - N/(1+10^{(10-pH-0.03T)}) \quad (1)$$

or:

- $NH_3$-N is the concentration of stripped ammoniacal nitrogen;
- $NH_4$ + N, that of ammoniacal nitrogen in solution in the liquid fraction.

It consists of entraining gases or volatile substances dissolved in water by means of a counter-current flow of steam, gas, or air through the liquid [9]. This method This method was used in Ashimota (Ghana) [10]. The procedure consisted of collecting samples of the liquid fraction at the station, analyzing them at the Lab'Eau - Hygiène Laboratory of UGANC, and interpreting the results at LEREA. Temperature and pH measurements were taken at six points, labeled A, B, C, D, E and F, from the water level of lagoon 1 (Table 2).

Laboratory analyses determined the N-$NH_4$+ concentrations. The application of the Azov and Goldman mathematical model (I) allowed for the calculation of the stripped N-$NH_3$ concentration. The non-ionized fraction (f) is the ratio (NHdNH4+) in lagoon 1 given by the equations

$$f = 1/[10^{[pKa-pH]} + 1] \quad (2)$$

or:

- pKa is the dissociation constant of the liquid fraction, given by relation (3).
- T is its temperature in $^0$K.

$$pKa = 0.0901821 + 2729.92 \quad (3)$$

Samples were taken at each point A, B, C, D, E, and F. The Azov-Goldman model was used to determine the average $NH_3$ and $NH_4+$ concentrations as a function of temperature (Table 2). Calculations of the average values of the non-ionized fraction, pH, and correlation coefficient yielded the results presented in Tables 1 and 2.

## 3. Results and Discussion

The results of the chemical parameters as well as the volatilization of $NH_3$ of the analyzed sludge appear in Tables 1 and 2.

### *3.1 Chemical Parameters of Septic Tank Sludge*

The averages of the different parameters obtained during the experiments are shown in the Table 1.

**Table 1 Average values of chemical parameters.**

| | Measurement points in lagoon 1 | | | | | |
|---|---|---|---|---|---|---|
| Settings | HAS | B | C | D | E | F |
| | 38.5 | 33.24 | 39.85 | 39.41 | 35.79 | 40.05 |
| $NH4^{+}$ NH3 pH | 29.42 | 24.99 | 31.8 | 31 | 28.75 | 30.15 |
| F | 9.56 | 9.64 | 9.62 | 9.66 | 9.65 | 9.62 |
| $R^2$ | 0.76 | 0.79 | 0.79 | 0.81 | 0.8 | 0.76 |
| | 0.905 | 0 84 | 0903 | 0.76 | 0 81 | 0.89 |

**Table 2 Volatilization of $NH_3$ at observation points over time as a function of pH and temperature.**

| Observation point | Volatilization of $NH_3$ in lagoon 1 for all observation points from 09:00 to 16:00 as a function of pH and temperature | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ph | | | Temperature in °C | | | Ammoniacal nitrogen NH3 in m IL | | |
| | 9-10 am | 12-1 pm | 3-4 pm | 9-10 am | 12-1 pm | 3-4 pm | 9-10 am | 12-1 pm | 3-4 pm |
| HAS | 9.48 | 9.58 | 9 63 | 28.12 | 34.47 | 33 68 | 25.65 | 31.67 | 30.93 |
| B | 9.59 | 9.65 | 9.67 | 28 48 | 33.15 | 34.10 | 25.97 | 24 17 | 25.79 |
| C | 9.48 | 9.67 | 9.71 | 34.20 | 35.41 | 29 96 | 30 21 | 34.35 | 31.09 |
| D | 9.60 | 9.68 | 9.69 | 28.40 | 35 43 | 35.77 | 27.95 | 30.46 | 37.45 |
| E | 9.62 | 9.67 | 9.68 | 28.77 | 33.36 | 33.71 | 25.50 | 29.60 | 31.14 |
| F | 9 60 | 9 63 | 9.62 | 29.11 | 31 | 30 33 | 30 28 | 26 36 | 33.80 |

From this table, we can see:

- A change in pH was observed across all observation points from 9:00 AM to 4:00 PM. The pH increased from 9.48 at points A and C (9:00-10:00 AM) to 9.71 at point C (3:00 PM-4:00 PM). This increase in pH is favorable to the stripping process.
- A gradual temperature increase occurred between 9 a.m. and 4 p.m., rising from 28.12 °C at point A (9-10 a.m.) to 35.77 °C at point D (3-4 p.m.). This increase is an ideal condition for the stripping process.
- A progressive evolution of the volatilization of ammoniacal nitrogen $NH_3$ during the day, going from 25.50 mg/L at point A (09-10 a.m.) to 31.67 mg/L at the same point (12-1 p.m.) to reach 37.45 mg/L at point D (15-16 p.m.).

Indeed, NH concentrations dominate throughout the entire body of water, and this explains the nitrogen volatilization.

The correlation curves of the $NH_3/NH_4+$ ratio as a function of pH at points A to F are shown in Figs. 3-8. Fig. 2 shows the correlation curve of the $NH_3/NH_4+$ ratio as a function of pH at point A. The coefficient of determination R2 = 0.9057, which means that 90.57% of the non-ionized fraction is explained by the regression model found. This coefficient of determination is an indicator of NH3 volatilization at point A. This coefficient of determination allows us to find the correlation coefficient $r = \pm\sqrt{\boldsymbol{R^2}}$. For $r^2 = 0.9057$, we obtain r = 0.95, which means that there is a strong correlation between the non-ionized fraction and pH, since r tends towards 1. [10]

Fig. 3 shows the correlation curve of the $NH_3/NH_4+$ ratio as a function of pH at point B. The coefficient of determination $R^2 = 0.8419$, meaning that 84.19% of the non-ionized fraction is explained by the regression model. This coefficient of determination is an indicator of $NH_3$ volatilization at point B, with $r = 0.9 > 0.7$ [11]. Fig. 4 represents the correlation curve of the $NH_3/NH_4+$ ratio as a function of pH at point C. The coefficient of determination $R^2 = 0.9034$, which means that 90.34% of the non-ionized fraction is explained by the regression model found.

This coefficient of determination is an indicator of the volatilization of $NH_3$ at point C, with $r = 90 > 0.7$ [11].

Fig. 5 shows the correlation curve of the $NH_3/NH_4+$ ratio as a function of pH at point D. The coefficient of determination $R^2 = 0.9510$, meaning that 75.10% of the non-ionized fraction is explained by the regression model. This coefficient of determination is an indicator of $NH_3$ volatilization at point D, with $r = 0.87 > 0.7$ [11].

Fig. 6 shows the correlation curve of the $NH_3/NH_4+$ ratio as a function of pH at point D. The coefficient of determination $FR^2 = 0.7510$, meaning that 75.10% of the non-ionized fraction is explained by the regression model. This coefficient of determination is an indicator of $NH_3$ volatilization at point D, with $r > 0.87$. [11]

Fig. 7 shows the correlation curve of the $NH_3/NH_4+$ ratio as a function of pH at point F. The coefficient of determination $FR^2 = 0.8939$, meaning that 89.39% of the non-ionized fraction is explained by the regression model. This coefficient of determination is an indicator of $NH_3$ volatilization at point F, with $r = 0.95 > 0.7$ [11]. These results allowed us to plot the daily volatilization curves as a function of pH and temperature (Table 2) and the correlation curves of the $NH_4+/NH_3$ ratio as a function of pH (Table 3).

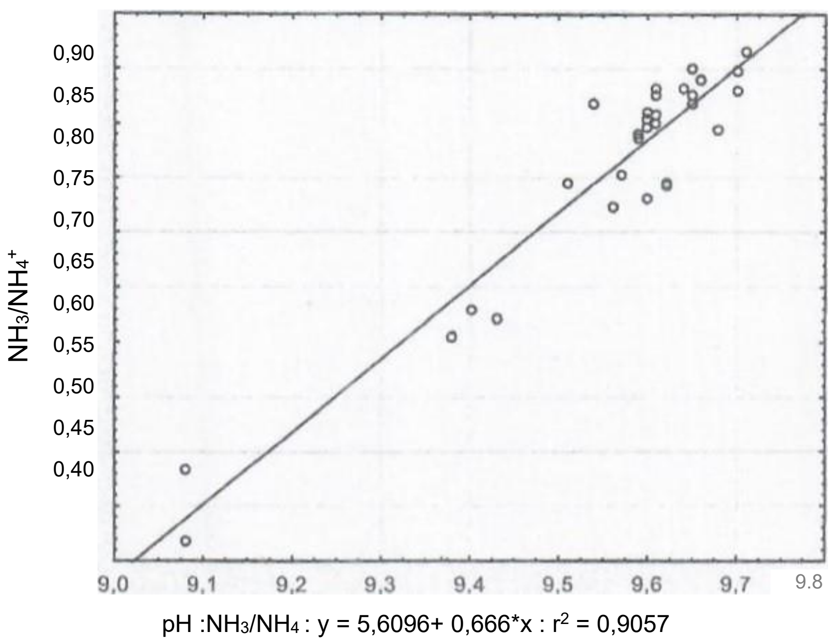
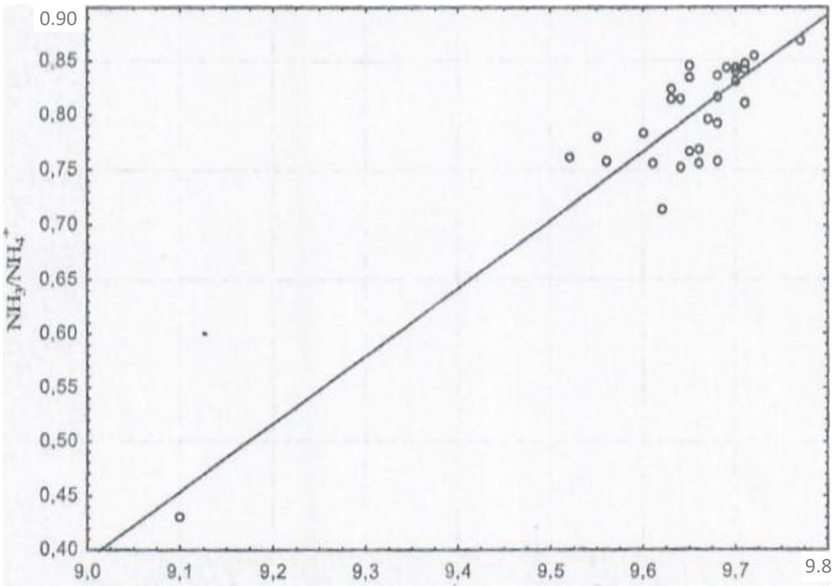



**Fig. 3 Correlation curve of the $NH_3/NH_4$* ratio as a function of pH at point A.**




pH :$NH_3/NH_4$ : y = 5,2473+ 0,6265*x

**Fig. 4 Correlation curve of the $NH_3/NH_4$* ratio as a function of pH at point B.**

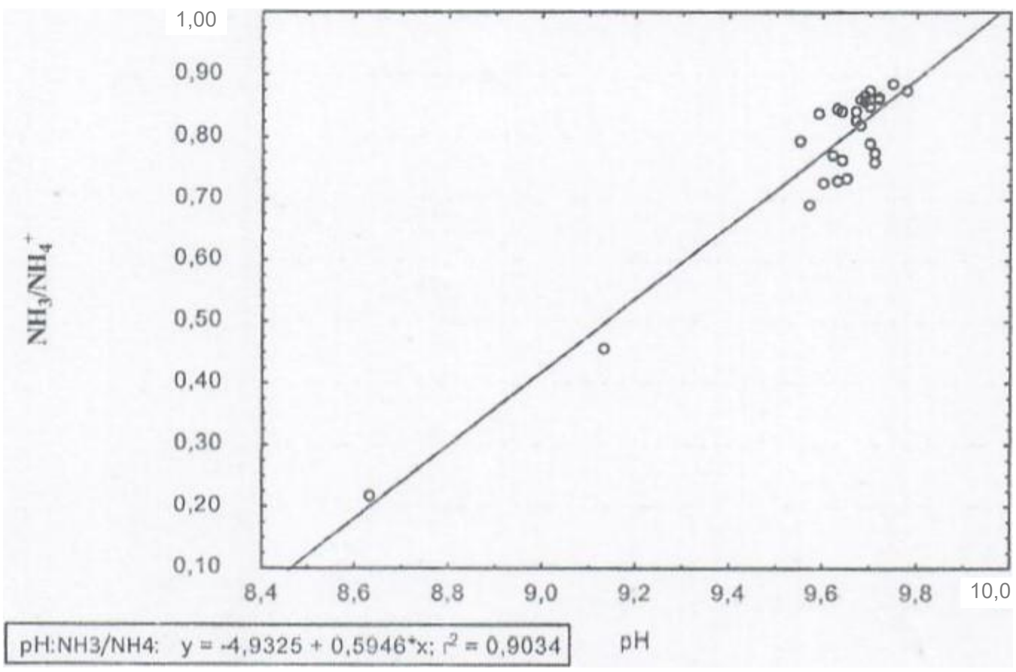



**Fig. 5 Correlation curve of the $NH_3/NH_4$+ ratio as a function of pH at point C.**

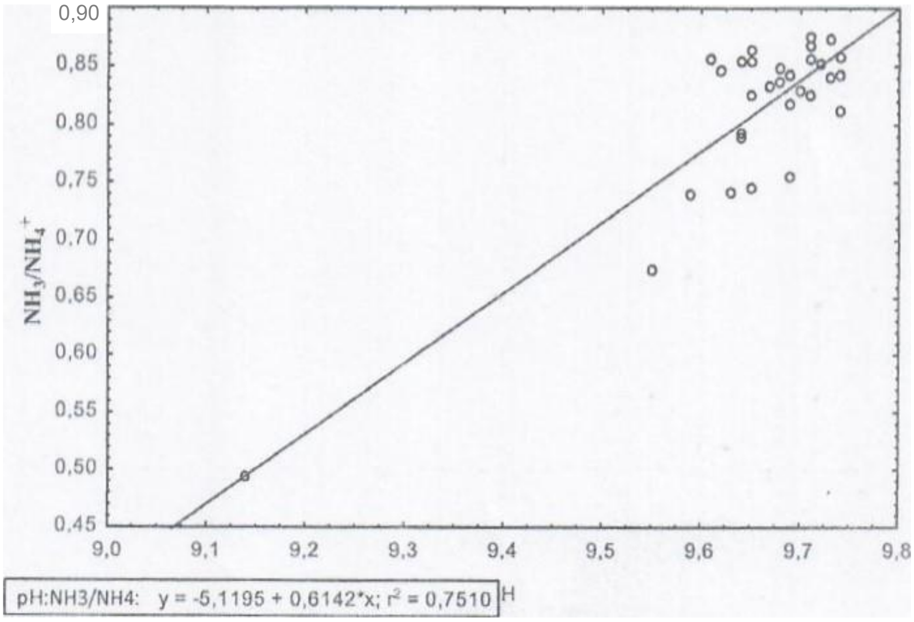
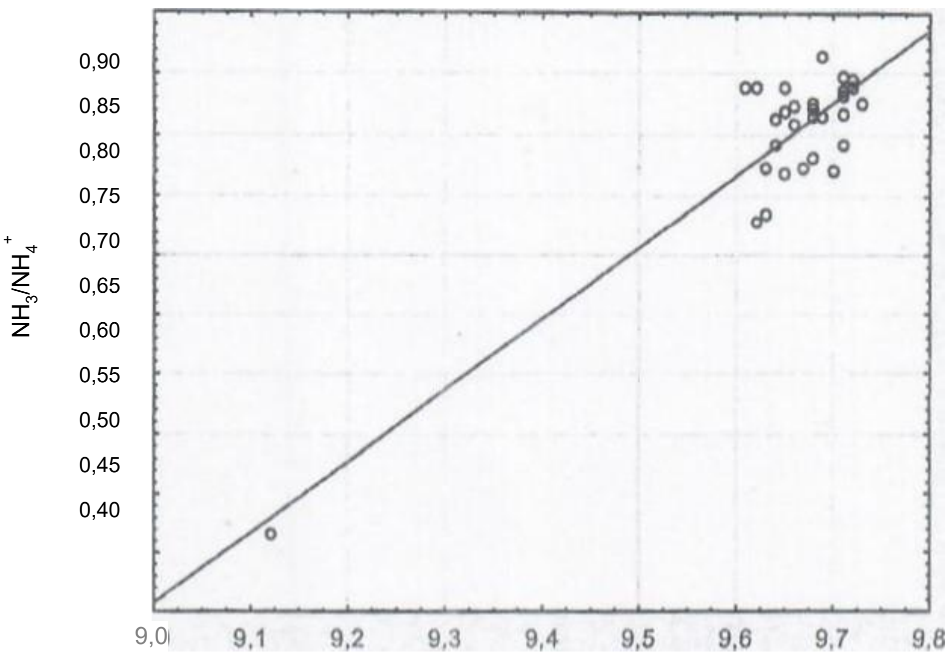



**Fig. 6 Correlation curve of the $NH_3/NH_4^+$ ratio as a function of pH at point D.**




pH :$NH_3/NH_4$ : y = 4,9824+ 0,5988*x $r^2$ = 0,8104

**Fig. 7 Correlation curve of the $NH_3/NH_4^+$ ratio as a function of pH at point E.**

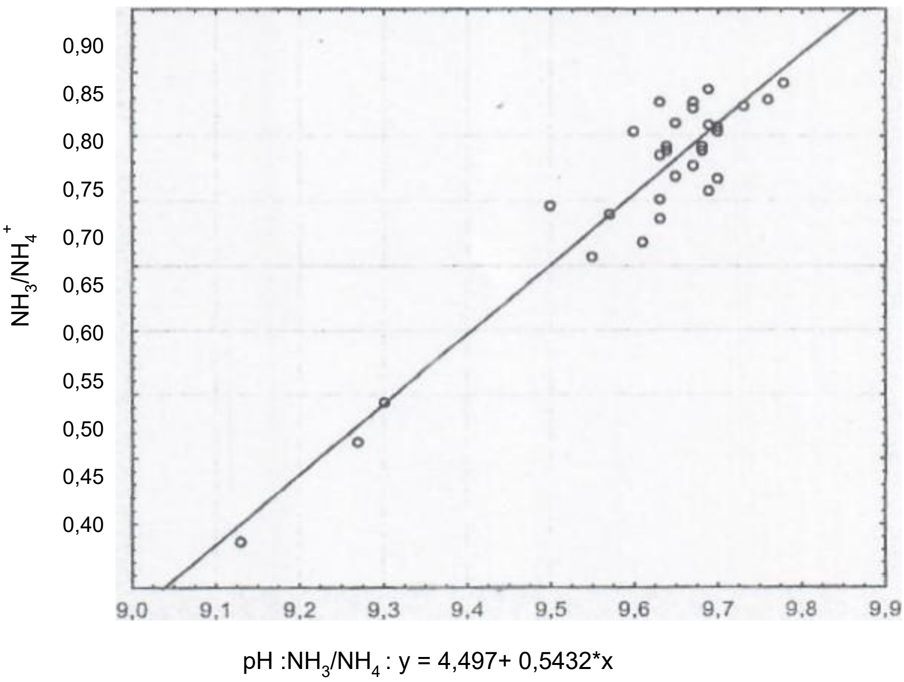



**Fig. 8 Correlation curve of the NH/NH4+ ratio as a function of pH at point F.**

The experiment aims to observe the process of conversion of N-$NH_{4+}$ into N-$NH_3$. Monitoring the evolution of pH and temperature in lagoon I, by applying the Azov and Goldman model, shows that the NHdNH4+ ratio, calculated for pH values recorded in lagoon 1, is in favour of the gaseous form, $NH_3$, which reinforces the hypothesis of the existence of a very active "Stripping" volatilization in lagoon 1[12]

The correlation analysis provided by Excel's analysis utility, using the "Linear Regression" module, yielded a set of results called "Detailed Report". From this report, the coefficient of determination $R^2$ was obtained for each observation point. For point A, the coefficient of determination $R^2 = 0.9057$, meaning that 90.57% of the non-ionized fraction is explained by the regression model. This coefficient of determination is an indicator of $NH_3$ volatilization at point A. It allows us to calculate the correlation coefficient r.

$\pm\sqrt{\boldsymbol{R^2}}$. For $R^2 = 0.9057$, we obtained r = 0.95, which means that there is a strong correlation between the non-ionized fraction and the pH, since r > 0.7. The other points are explained in the same way.

## 3. Discussion

The correlation coefficient r = 0.95 > 0.7, which means there is a strong correlation between the non-ionized fraction and the pH, also confirms the existence of very active $NH_3$ volatilization at this station. This confirms the idea of A. [13] who states that if R is greater than 0.7 is an indicator of $NH_3$ volatilization indicating good performance of the model.

## 4. Conclusion

Monitoring the evolution of temperature (32.15 °C) and pH (9.62) in lagoon I (experimental phase) shows that nitrogen (N-$NH_3$) volatilization is very active, based on the results obtained by applying the Azov and Goldman model. These results, subjected to statistical analysis using an Excel spreadsheet, yield a correlation coefficient r = 0.95 > 0.7, which means there is a strong correlation between the non-ionized fraction and pH.

The results obtained suggest that this model could be used in the design of new stations.

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