# Influence of the water nature on the two-phase flow in an air-lift column

## ABSTRACT

The objective of this study is to determine the phase indicator functions of a two-phase flow in an air-lift vacuum column. These functions are the vacuum rate, the interface speed and bubble size, the flow rate and the speed of the liquid phase. The vacuum lift air column that is the subject of this study is based on the principle of air lift and flotation, all under vacuum. In its operation, the column combines hydraulic pumping, solute transfer and particle phase separation functions, which has the particularity of minimizing energy costs. The process of air-lift columns under vacuum is under development and the experimental study of its hydrodynamics is one of the determining axes in the course of exploration with a view to optimizing its design and functioning. The experiments were carried out on a vertical column composed of two concentric plexiglas tubes connected to a water recirculation tank and to a vacuum pump. For all of the experiments, demineralized water and salt water are used and the flow rate of which is measured by a flow meter. The experimental analysis is carried out using two-phase instrumentation consisting of a bi-probe and the use of experimental techniques has enabled a better understanding of the hydrodynamics of the two-phase flow.

*Keywords: Bubble size, speed, vacuum rate, water quality, flow*

## 1. INTRODUCTION

The study of the generation and behavior of bubbles within them requires to take into account the conditions of pressure prevailing in the column of the air injection and of the nature of the liquid used [1]. Regarding the influence of salinity on the two-phase behavior of the liquid, even if observations regularly emerge as the difference in the sizes of the bubbles, no satisfactory explanation has yet emerged. The research work entitled "prediction of micro-bubble dissolution characteristics in water and seawater" [2], experimentally confirms the commonly observed results concerning the size of the lower bubbles in sea water compared to salt water, but does not explain the reason, and just mentions the probable influence of the change in surface tension or ionic effects. The complete source found is the thesis work [3] on the local analysis of the transfer of matter associated with the formation of bubbles generated by different types of orifices. It clearly synthesizes in its bibliographic part many aspects of the problem of the formation of bubbles by air injection.

## 2. EXPERIMENTS ON THE AIRLIFT COLUMN

Previous studies [4] conducted on the effectiveness of an air lift, have highlighted different two-phase behaviors between freshwater and seawater. In order to know the source of these differences, the most striking of which are reside in differences in bubble size and coalescence capacity, column experiments of small volume (about 30 L) were carried out. The diameter of this column corresponds to that of the inner column of the air lift studied and presented to the INSA [5]. This column corresponds to a new experimental setup, these first studies make it possible to define the possible applications and the limits of the test bench. The advantage of the column lies in these dimensions which make it more handleable and allows easier study of various waters than in an air-lift assembly.

## 2.1. THE PROTOCOL

In the perspective of a complete study on the column, it is interesting to characterize the following solutions:
- Distilled or fresh water, at room temperature (about 25 ° C), cold (about 10 ° C or 15 ° C), hot (about 35 ° C);
- Seawater with various salinity: 5 ‰, 15 ‰, 25 ‰, 35 ‰;
- High salinity water 150 ‰;
- Sea water;
- Rearing water;
- Fresh water in the presence of surfactant;
- Fresh water in the presence of cooking salt 35 ‰.

In the following configurations: for different flow rates, at different heights of the optical probe, in pressure and in vacuum, for different diffusers (agglomerated sand, ceramic and free air).

## 2.2. CHARACTERIZATION OF SALT WATER

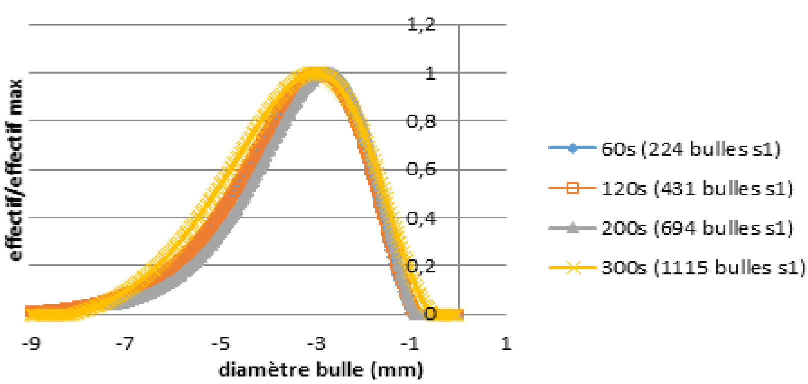
To homogenize the salt solution, the column works under vacuum overnight at an air flow rate of 15L / min. However, the dissolution time and the agitation within the column do not allow a homogeneous solution to be obtained. The transparent bottom flange allows a deposit of salt to be observed at the bottom of the column, under the injector. Thus, the measurements were carried out for a salinity of 27.8 g / l. It was nevertheless chosen to carry out these measurements at this salinity, because the addition of salt a few minutes before the acquisitions would have created an even more heterogeneous solution.

## 3. THE FRESHWATER SOLUTION IN THE PRESENCE OF SURFACTANT

0.3 ml of surfactant was added to 23 l of fresh water. The main idea was to homogenize the solution overnight like seawater reconstitution, but on the first bubbling, the surfactant created a thick foam overflowing from the column. We note that after 24 hours of rest, the foaming is much less strong. This is likely due to the spread of the surfactant throughout the volume. By injecting air too soon after the addition of surfactant from the top of the column, therefore in the region of the free surface, the production of bubbles has been enormously favored [6], [7], [8].

## 4. RESULTS

To find out the acquisition time allowing a sufficient number of bubbles to pass to relevant statistical processing, a comparative study is carried out. In Figure 1, the particle sizes are calculated from measurements taken over 60, 120, 200, 300 seconds for demineralized water under vacuum at an air flow rate of 4.08L / min. The ordinate represents the number of bubbles of diameter included in the class given on the abscissa, and normalized by the number of bubbles present in the class of maximum size. It can be seen that the results of the treatment are very similar, which suggests that it is possible to acquire measurements of fairly short duration. This conclusion is at least valid in bubble flow regime. For higher flow rates, the minimum acceptable time is likely to increase. A similar approach had been carried out for slug churn, but artifacts due to the acquisition itself such as the drift of the probes zero, degrade the readability of the results. These artifacts are, besides the simple fact of being able to accelerate the calendar of manipulations, are another reason for choosing short acquisition times.



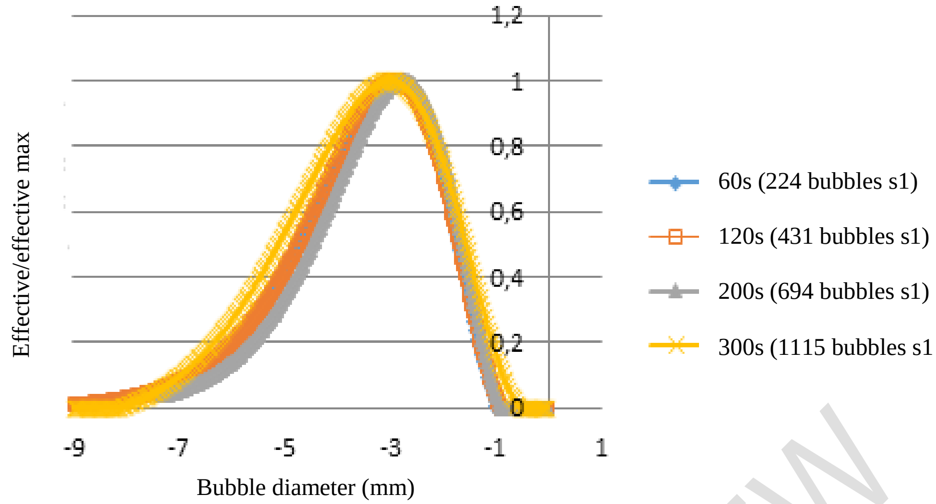



Figure 1: Convergence of measurements

The convergence depends on the air flow injected into the air lift column [9], in order to obtain satisfactory results, the measurements in demineralized and salt water under vacuum are carried out for an acquisition time of 300s (see figure 1). The number of bubbles intercepted by the probe in a mixture of pressurized salt water is low and in this case, the acquisition time is doubled: 600s. The following figure 2 represents the dispersion of the results obtained for the rising speed of the bubbles according to different calculation methods proposed by the software in the case of an air flow in demineralized water.

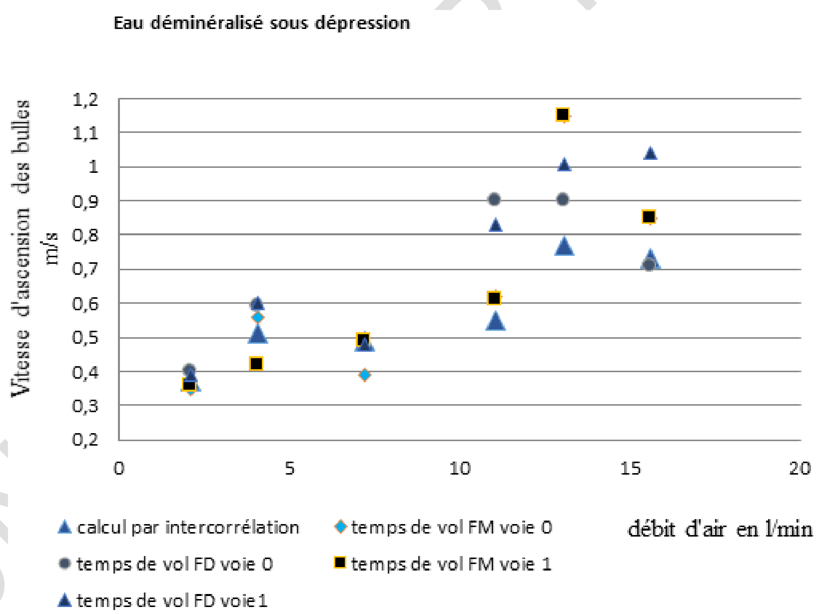



Figure 2: Bubble speed as a function of different calculation mode

From a flow rate of 4 l / min, the dispersion between the value of a speed for the same acquisition is around 33% (see Figure 2). The data collected for the following measurements are those given by the cross-correlation method. Because if this graph shows that for data processing, there is no better or more precise method than another, the intercorrelation method offers, by an intercorrelation coefficient greater than 0.7, a validity index of measurement.

### 4.1. FLOW-PRESSURE COUPLING

In depression, the points obtained are a function of a coupling between the flow rate and the pressure which vary respectively from 0 to 18 L / min and from - 0.5 to - 0.43 bars. Each point is a separate state. The valve of the buffer tank was not regulated during the manipulations, whereas this would have made it possible to stabilize the depression within the column and to treat the evolution of the results for increasing flow rates in a more coherent manner.

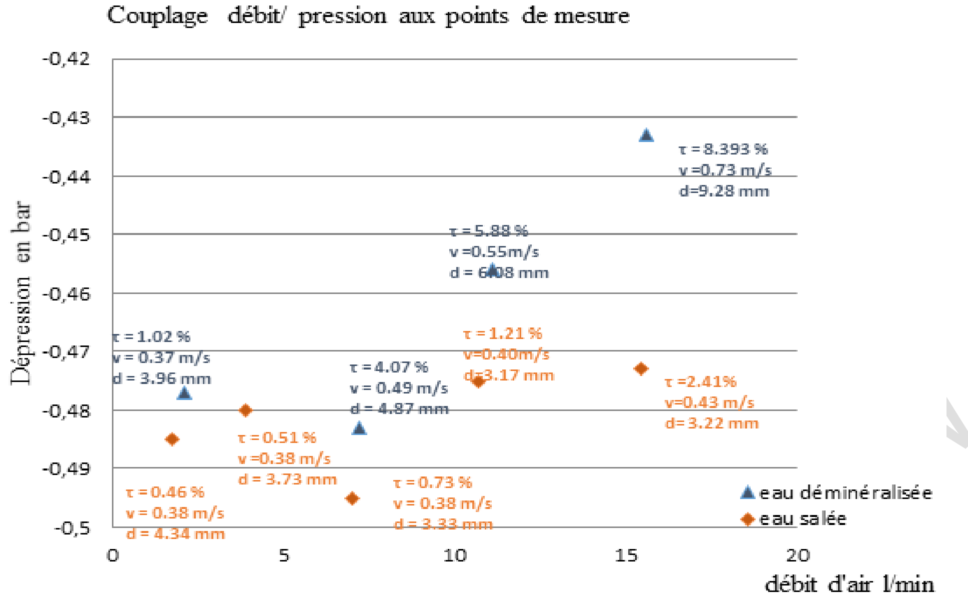



Figure 3: Pressure variation as a function of flow

A decrease in depression and an increase in flow rate qualitatively influence in the same way by a general increase in pressure within the column in Figure 3. The variation in flow rate and depression is almost monotonous in the case of demineralized water and salt water. Only the flow of 7 l / min for the two waters corresponds to a higher depression than for the lower flows and the linearity is no longer respected. Thus, the evolution of the data (ascent speed, diameter, void rate) according to the flow gives erroneous information, but makes it possible to define consistent trend curves. Care must be taken when processing the values obtained for the flow rate of 7 l / min.

## 4.2. DATA PROCESSING

### THE DIAMETER OF THE BUBBLES

For demineralized water under vacuum, a large increase in the diameter of the bubbles is observed when the flow of injected air increases. For 15 L / min, the average diameter is 9.3 mm while the average diameter of the bubbles for the other three measurements seems to be capped at 4 mm for a flow rate of 15l / min Figure 4. A change of scale makes it better understand the differences between pressurized and vacuumed salt water and pressurized demineralized water.

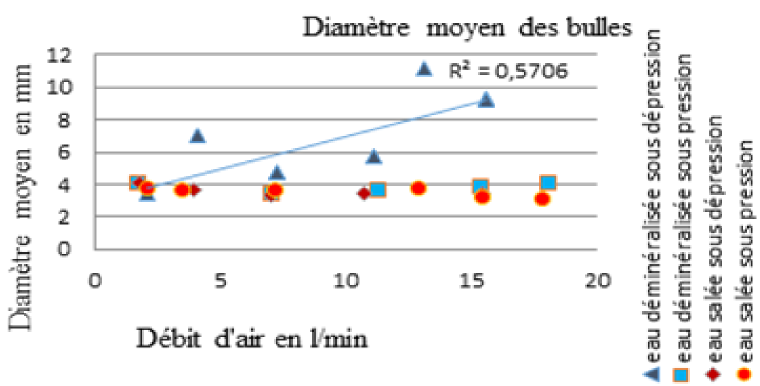



Figure 4: Average diameters as a function of various water

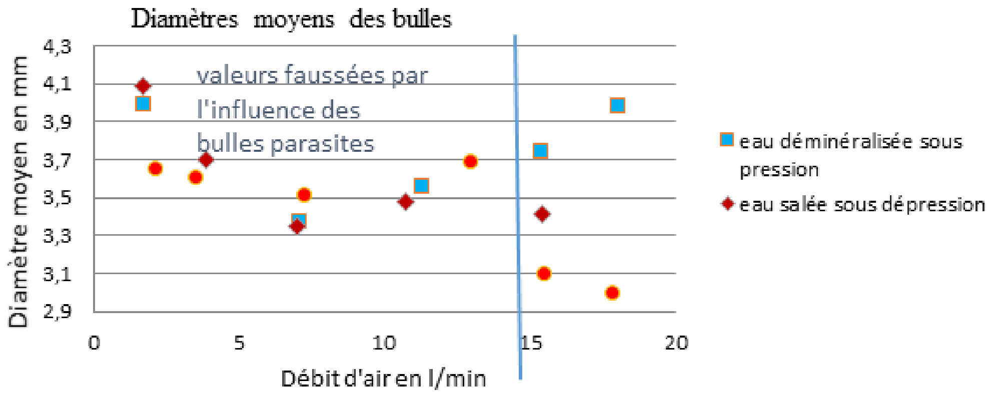



Figure 5: Bubble diameters for different types of water

Air flows below 14L / min, the average diameters are distorted (Figure 5). At low flow, fewer bubbles are created and the share of parasitic bubbles due to a crack in the diffuser is large and modifies the average value of the bubbles perceived by the probe. Too few points were made for flow rates greater than 15 l / min in order to conclude when the evolution of the average diameter of the bubbles. Finally, it is the particle size study which makes it possible to determine the most represented diameter which gives a conclusion without the parasitic effect of the cracked bubbler.

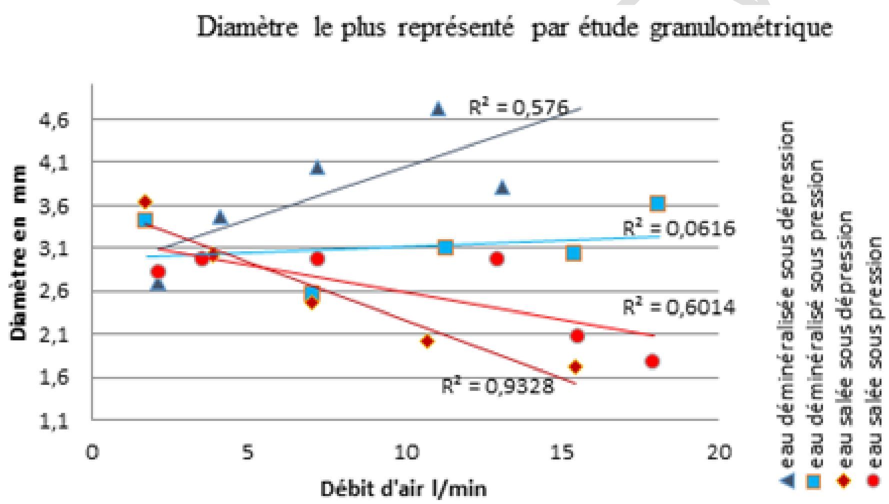



Figure 6: Particle size study for different flow rates

The bubble diameter most represented in demineralized water under vacuum is smaller than the average diameter indicated by the previous graph: it is of the order of 4.7mm at 12l / min figure 6. The increase in the flow of injected air under pressure in demineralized water corresponds to a slight increase in the average diameter of the bubbles and close to 3 mm at 15 l / min. In salt water, the most represented average diameter decreases as the flow rate increases. According to this graph, coalescence does not take place in a saline environment since the diameter of the bubbles decreases.

These two different trends are accentuated by vacuum injection, that is to say that in demineralized water, the diameter of the bubbles is greater at a given flow rate under vacuum than under pressure. Whereas for salt water, the depression decreases the average diameter of the bubbles compared to the pressurization for a given flow. This would mean that in demineralized water, the depression favors the coalescence of the bubbles and that in salt water, the depression maintains the non-coalescence of these and however, the probe does not allow to acquire the data necessary for such a hypothesis.

### 4.3. ASCENT SPEED

The rate of ascent of the bubbles increases with increasing air flow for demineralized water and salt water under vacuum, but decreases slightly for salt water under pressure. This is explained by the correlation of the speed of the bubbles with respect to their diameter. A bubble of larger diameter has a higher speed. These trends in the evolution of the diameter and rise of the bubbles are similar for demineralized water, but which is not the case for salt water. This divergence of salt water can be explained by the fact that microbubbles are not taken into account in the calculation of velocities [10].

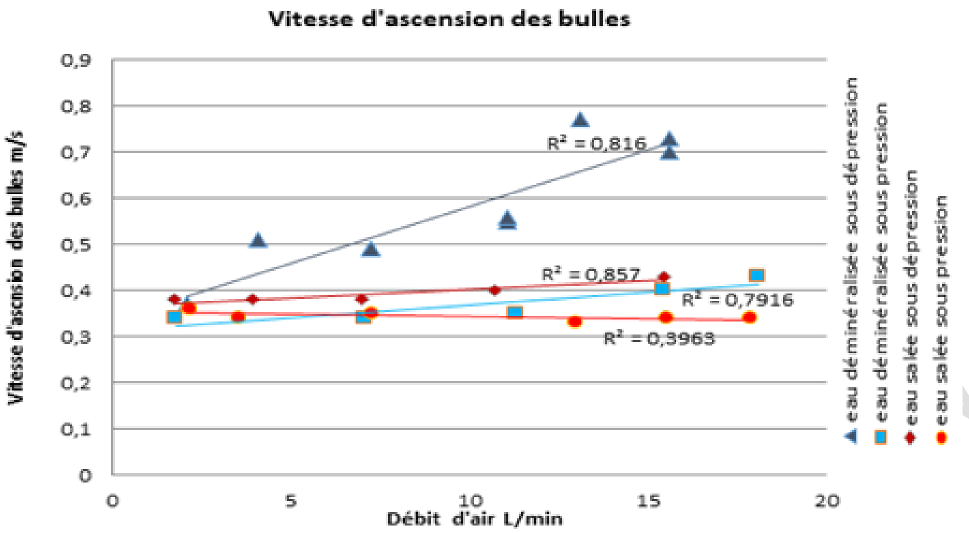



Figure 7: Bubble velocity for different air flow rates

Indeed, the data in Figure 7 are also biased by the size of the probe which does not measure a bubble diameter less than the spacing of its tips, ie 2mm. We know that the population of very fine bubbles (therefore <2mm) in seawater is preponderant due to bubbling and non-coalescence.

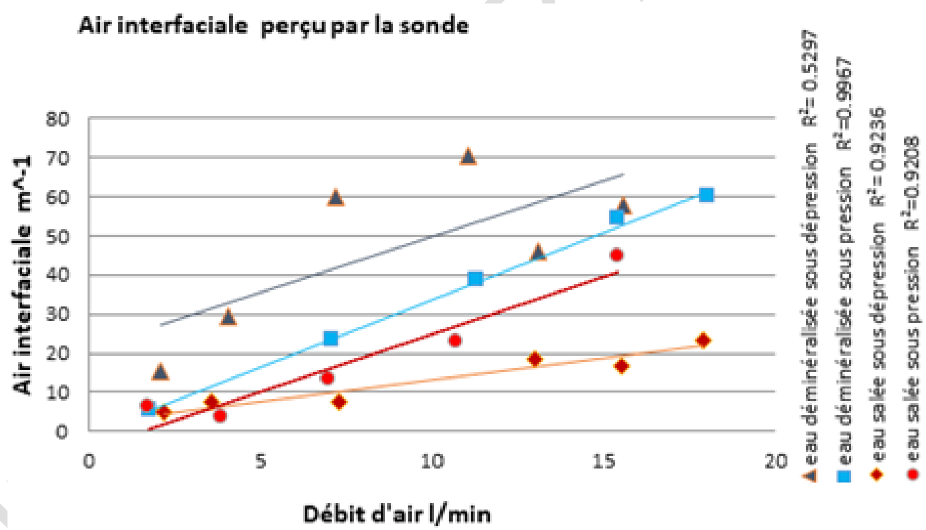



Figure 8: Variation of interfacial air as a function of air flow

The interfacial air increases when the air flow increases for demineralized water as well as for salt water, whether it is under pressure or under vacuum (see Figure 8). This result is consistent in salt water for an increase in air flow, hence when the diameter of the bubbles decreases, the interfacial air for the same flow increases. On the other hand, the salt water flow has more bubbles than the demineralized water flow. These bubbles are not perceived by the probe and falsify the measurements. Because for the same air flow, the surface developed by many microbubbles is larger than that developed by a smaller number of larger bubbles. This means that the actual values of the interfacial air of salt water are probably higher and higher than those of demineralized water.

## 4.4. THE VACUUM RATE

Two methods allow the measurement of the vacuum rate: acquisition by the probe and volumetric measurement between static water and the mixture of air and water.

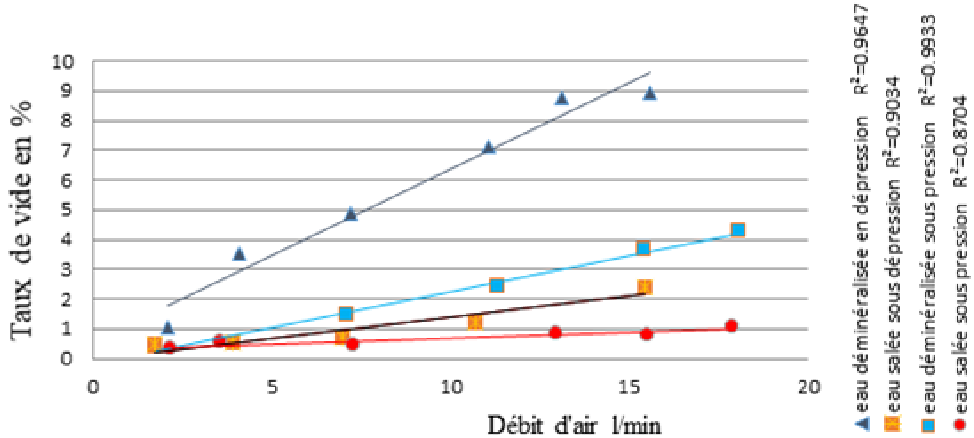



Figure 9: Effect of vacuum or pressure on the vacuum rate

The vacuum rate increases with the air flow. Depression leads to a higher vacuum rate (Figure 9). For a given flow rate than pressure, the effect is all the more noticeable on demineralized water. But this is due to the nature of the probe and these limits of perception of bubbles of less than 2 mm.

**VACUUM RATE BY VOLUMETRIC STUDY:**

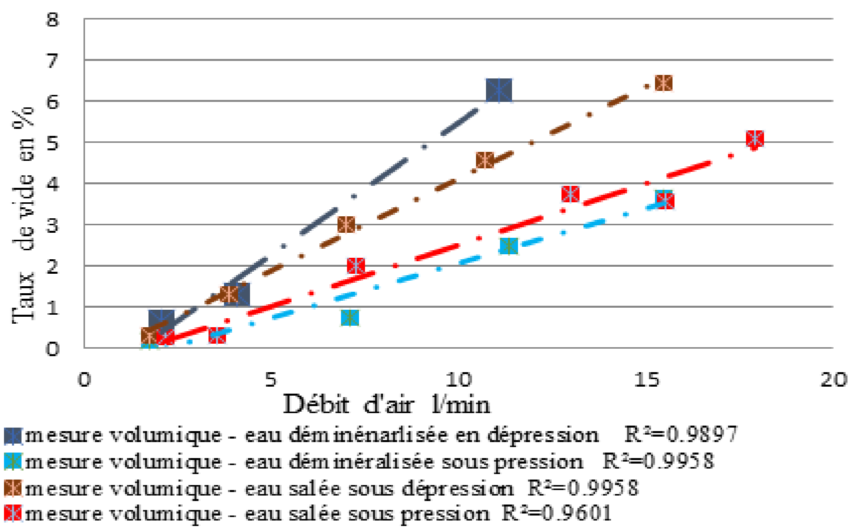



Figure 10: Evolution of the empty rate depending on the type of water

Figure 10 highlights the difference between the vacuum injection method of air, the vacuum rate is greater than under pressure for a given flow. Only three points were noted by this method for demineralized water, the trend curve obtained can thus be questioned.

**RELEVANCE OF THE METHODS FOR CALCULATING THE VACUUM**

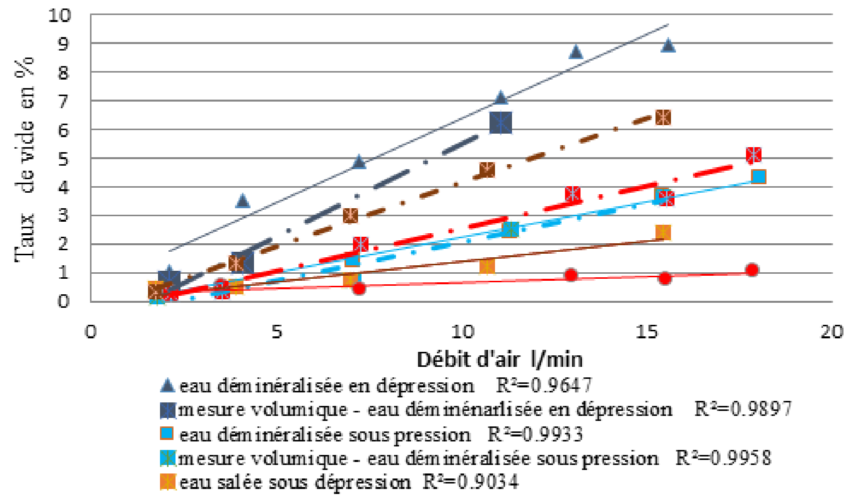



Figure 11: Calculation of the vacuum rate as a function of the air flow

For demineralized water, the two methods give similar results. A difference is noted for salt water which has microbubbles which are not perceived by the probe. The angle described between the trend curves characteristic of the two methods for pressurized and vacuumed salt water corresponds to the volume of vacuum occupied by bubbles of diameter less than 2 mm. This vacuum volume characteristic of fines and microbubbles is greater under pressure where it presents 79.4% of the total volume, than under depression, where it represents 62.3%. For demineralized water as for salt water, the depression favors the coalescence of the bubbles. This result disagrees with the conclusion obtained by studying the most representative diameters. However, the conclusion drawn from the study of diameters is unreliable due to the non-perception of fine bubbles by the probe in figure 11.

## 5. CONCLUSION

According to the experiments, it follows that the measurements carried out do not inform when the possible influence of the surface tension on the size of the bubbles and their capacity to coalesce. Complementary measurements of fresh water at three distinct temperatures -10, 25 and 40° C within the column were carried out, an experiment which is described in this manuscript would make it possible to verify the hypothesis that the surface tension influences the size bubbles within a solution [11]. In the case where the surface tension really influences the size of the bubbles and their capacity to coalesce, the high value of the surface tension obtained for water saturated with salt offers new perspectives in the applications of the vacuum column lift. It has not been possible from the experiments carried out to demonstrate the role of surface tension on the size of the bubbles and their ability to coalesce.

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