

Contribution to the study of the phenomenon of scaling of pipes by groundwater in the region of Tahoua: Study of the variation of the concentration of pure calco-carbonic solutions

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Abstract

Groundwater of some localities in Thaoua region are charged in hydrogen carbonate ions and calcium. During their exploitation these waters essentially form adhesive CaCO_3 deposits on the partitions of facilities transporting theme: This phenomenon corresponds to what is called scaling. To understand this phenomenon kinetics of precipitation of the CaCO_3 while using of the controlled degassing method were studied. This method consists stripping the CO_2 of the solution while stealing air and the CaCO_3 hurls down. So a set of tests has been done from the pure calco-carbonic solutions to varied concentrations. The kinetics has been followed while measuring it $[\text{Ca}^{2+}]$ and the pH of the solution according to the time. The time of germination has been marked with the simultaneous fall of the pH and it $[\text{Ca}^{2+}]$. The leading principle of precipitation CaCO_3 and the elimination CO_2 of the solution. In short the more water contains calcium the more it is scaling and the time of germination decreases with the concentration in calcium, we continued this survey while varying the temperature, flow of air etc.

Keywords: Scaling; Carbonate of calcium; Thaoua; Groundwater

1. Introduction

Scaling is the formation of deposits on the internal walls of pipes and structures that carry water. This deposit is generally made up of calcium carbonate, calcium sulfate and silica. Scale deposits in water systems often result in ample technical and economic problems [1]. During its circulation, this water gives rise to the phenomenon of scaling, which leads to reductions in flow and can cause valves and taps to seize. The maintenance of scaled installations or the replacement of pipes is very expensive. Scale formation is the cause of certain diseases: kidney stones and calcifications of the cardiovascular system. Commonly encountered scales in water systems are CaCO_3 , CaSO_4 , SrSO_4 , BaSO_4 , CaF_2 , $\text{Ca}_3(\text{PO}_4)_2$, silica, and silicates. Scaling occurs when the concentration of a sparingly soluble salt exceeds its solubility in water. It usually results from changes in pH, temperature, outgassing or pressure that impact the solubility of the salts, and a concentration or evaporation process. For instance, when the water temperature increases, the solubility of CaCO_3 decreases which results in precipitation onto heated surfaces [2].

In Tahoua region, the population's drinking water supply is provided by groundwater. These aquifers constitute one of the main reserves of groundwater in Niger. These aquifers have great extensions and depths due to the geology of the region, and are for the most part highly charged with hydrogen carbonate and calcium ions. Thus, during their exploitation, these waters form adherent deposits made up essentially of CaCO_3 on the walls of the installations

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transporting them. [3]. This constitutes a major obstacle on the transport and distribution of these waters to the population.

Scientists have long been interested in the problems of scaling, in order to promote a refined control of the precipitation of calcium carbonate (scale), several methods have been developed, which are classified into two groups: electrochemical methods and non-electrochemical methods. The controlled degassing method, which is a non-electrochemical method, was the subject of this study. It consists in provoking the precipitation of calcium carbonate by a degassing (displacement of the calco-carbonic equilibrium in the direction of formation of calcium carbonate) of the solution to be studied [4] [5]. By following the pH values and the calcium concentration over time, a description of the precipitation kinetics of CaCO_3 can be made. This study is focused on the study of the variation of the concentrations of pure calcium-carbonate solutions.

1.1. Presentation of the study Area

The Tahoua region has an area of approximately 114,425 km² and is located between 13°20' and 18°40' north latitude and between 3°50' and 7° east longitude.

Administratively, it is bordered to the north by the Agadez region, to the east by the Agadez and Maradi regions, to the south by the Federal Republic of Nigeria, and to the west by the Dosso and Tillabery regions, and finally the Republic of Mali (Fig.1). It is composed of 12 departments which are Abalak, Bagaroua, Birni N'Konni, Bouza, Illéla, Keita, Madaoua, Malbaza, Tahoua, Tassara, Tchintabaraden, and Tillia.

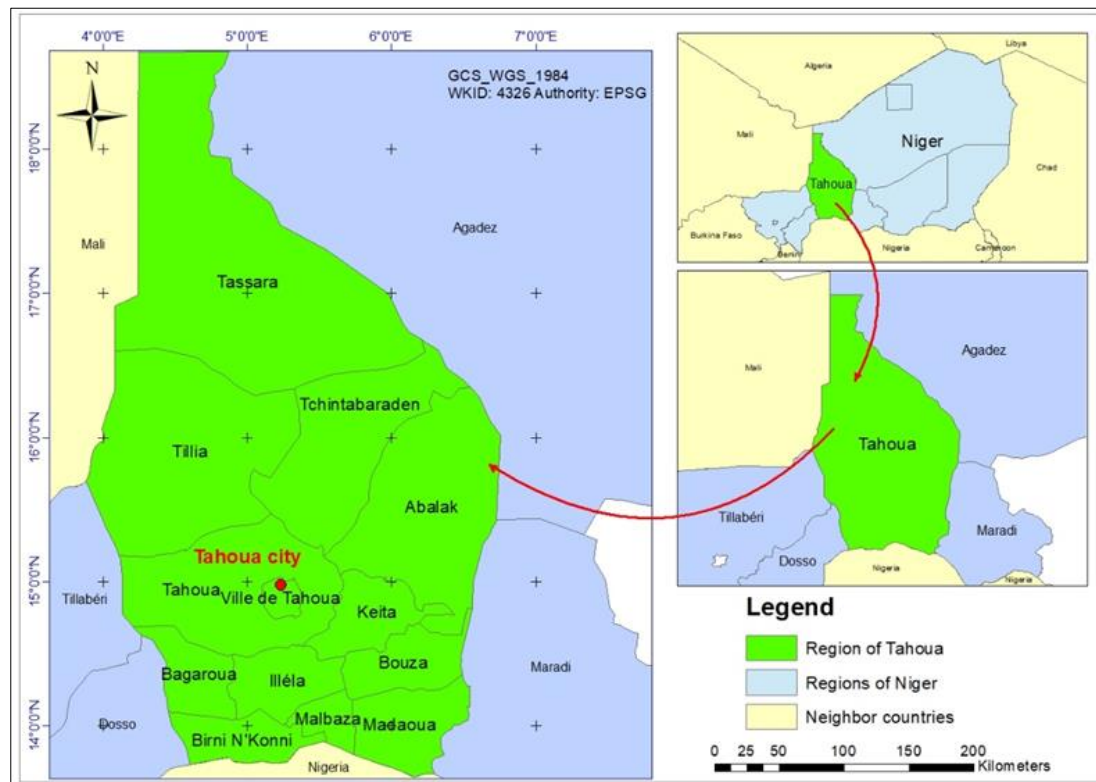


Figure 1 Study area

1.2. Geology and Hydrogeology of the Study Area

The geological context of Tahoua region is marked by a great diversity of geological formations, located in large sedimentary basins. The main formations encountered in this region are Cretaceous continental deposits consisting of fluvial, lacustrine and deltaic deposits and composed mainly of sandstones, clayey sands and clays, it is also noted the presence of silicified woods and remains of dinosaurian, crocodilians ; the Hamadian Continental, essentially constituted by coarse sandstones more or less clayey, met in the southern part of the region; the marine deposits of the Upper Cretaceous constituted by clays, calcareous sandstones, white limestones, gypsiferous clays, marine limestone alternations; the marine deposits of the Paleocene-Eocene, constituted by limestones, marno-limestones, marls and shales of low depth [6]; the continental Cenozoic deposits which correspond to the deposits of the Terminal Continental

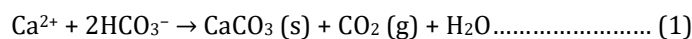
designating all the quartzo-kaolinic detrital formations with siderolitic facies of post-Eocene middle age and anteQuaternary; and finally the Quaternary deposits constituted by fixed dunes covering indifferently the underlying Cretaceous and Tertiary formations, living dunes in the northern part of the region, and alluvial deposits in the valleys of the region.

According to the hydrogeological characteristics, Tahoua region also has five aquifer units according to its geology which are the aquifers of the Intercalary/Hamadian Continental, the aquifer soft he Upper Cretaceous marine, the Paleocene aquifers, the aquifers of the Terminal Continental, and finally the Quaternary aquifers [7].

The geological and hydrogeological characteristics of Tahoua region shows then the aquifers of this region have great extensions and depths due to the geology of the region, and are for the most part highly charged with hydrogen carbonate and calcium ions. Thus, during their exploitation, these aquifers form adherent deposits made up essentially of CaCO_3 on the walls of the installations transporting them. This constitutes a major obstacle on the transport and distribution of these waters to the population.

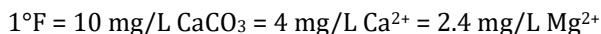
2. Material and methods

The controlled degassing method was developed by Henri Roques and his collaborators at the Laboratory of Chemistry and Environmental Engineering (LCGE). It has been the subject of various additions over the last few years concerning the addition of recent analytical techniques. The precipitation of calcium carbonate is caused by a degassing (displacement of the calco-carbonic equilibrium in the direction of formation of calcium carbonate) of the water to be studied by a working gas, most often the atmospheric air. The calcium carbonate precipitates according to the following reaction showed in equation 1:



The recording of pH values and calcium concentration allows a complete description of the precipitation kinetics.

2.1. Preparation of pure calcium carbonate solution at 20° F



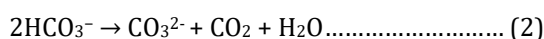
Using an electronic balance, 200 mg of pure CaCO_3 is weighed, which is placed in a 500 mL beaker, and 200 mL of distilled water is added for homogenization, then the content is transferred to a 1L bottle; and we complete up to the line gauge, then the flask is stirred with a magnetic stirrer and a magnetic bar which is already introduced into the flask, by bubbling the solution with CO_2 , under the effect of carbon dioxide, the calcium carbonate dissolves completely and thus a pure solution of calcium carbonate of 20° F is obtained. All solutions were prepared according to the same protocol.

3. Results and discussion

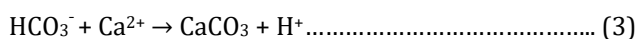
3.1. Study of pH evolution

The accelerated scaling curve represented in figure 2, showed the evolution of the pH as a function of time.

The curve represented in figure 1, shows the evolution of the pH of the studied solution according to the degassing time. It can be seen that from the beginning of degassing the pH value increases to reach a maximum after 40 minutes. During this phase, the monitoring of the concentration of Ca^{2+} by complexometric dosage with EDTA was carried out and shows no evolution. It is assumed that in this first phase, we have a release of dissolved CO_2 according to equation (2)



This could explain the increase of the pH of the solution: it is the state of metastability, this state ceases abruptly at the time T_g which we will define as the time of germination and is manifested on the pH which shows a fall which one can put in relation to the release of protons at the time when the precipitation of the calcium carbonate starts according to the following reaction showed in equation 3:



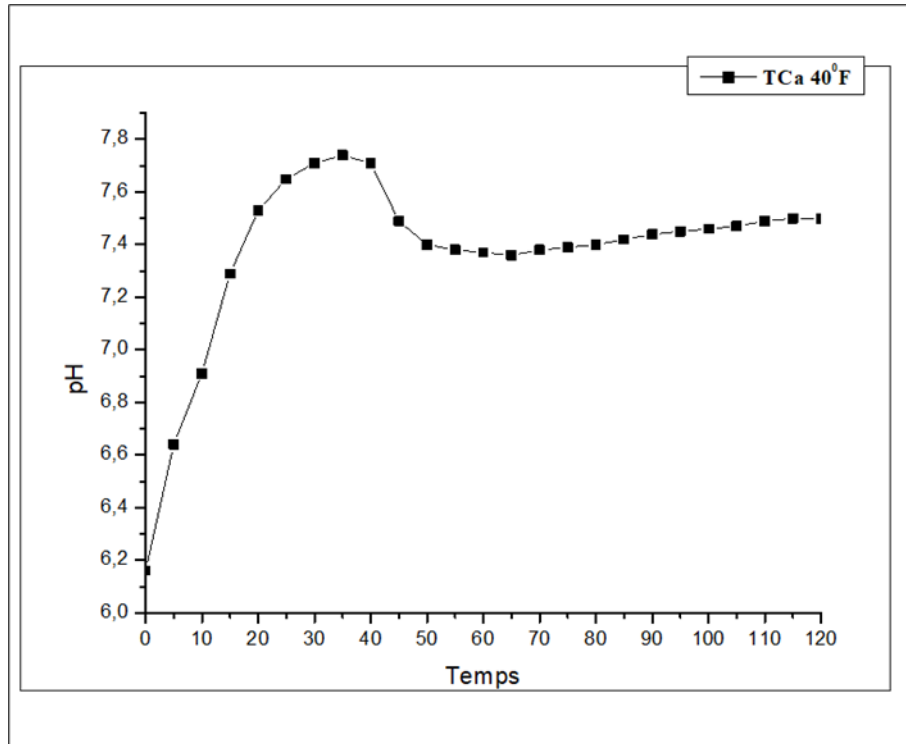


Figure 2 Evolution of pH versus time of a pure calcium-carbonate solution of 30o F

This mechanism of formation of CaCO_3 from HCO_3^- and Ca^{2+} was advanced by H. ROQUES et al cited by Elfil. This decrease of the pH continues until time T beyond which it starts to rise slowly. At time T the precipitation rate according to (2) has slowed down sufficiently and the degassing rate becomes higher than the release rate of H^+ protons. At time T_g , pHg was defined as the germination pH.

3.2. Study of the variation of the concentrations of the pure calco-carbonic solutions

3.2.1. Evolution of the pH of solutions

The Figure 3 showed the variation of pH of solutions at different concentrations as a function of the degassing time.

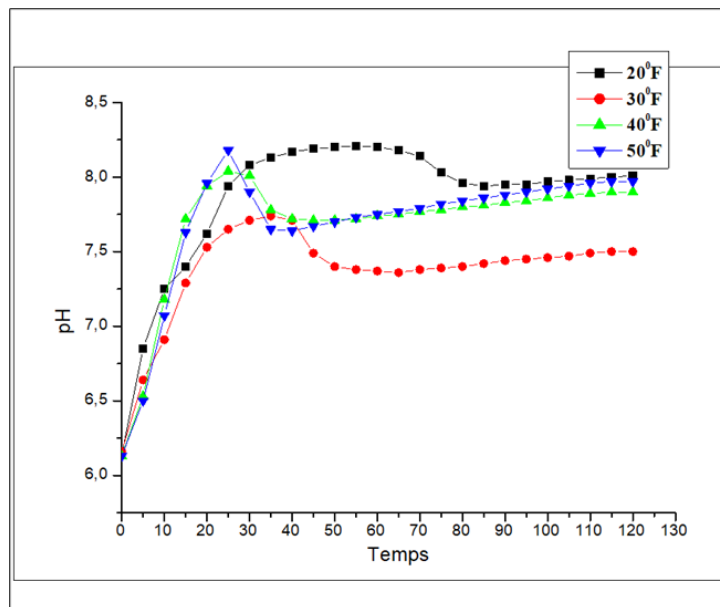


Figure 3 pH variation of solutions at different concentrations as a function of degassing time

The analysis of the curves of figure 2 shows that the part corresponding to the rise of the pH is identical whatever the concentration of the solution, but the fall of the pH which corresponds to the beginning of the germination varies according to the concentration of the solution. The table 1 summarizes the various times observed for the various concentrations of the pure calco-carbonic solutions

Table Various times observed for the various concentrations of the pure calco-carbonic solutions

Pure calcium carbonate solutions	200 F	300 F	400 F	500 F
Germination time Tg (in mn)	60	40	35	30
pH at germination	7.37	8.17	8.01	7.9

3.2.2. Evolution of Ca^{2+} concentration as a function of degassing time

The Figure 4 shows the evolution of the Ca^{2+} concentration of pure calcium-carbonate solutions at different concentrations.

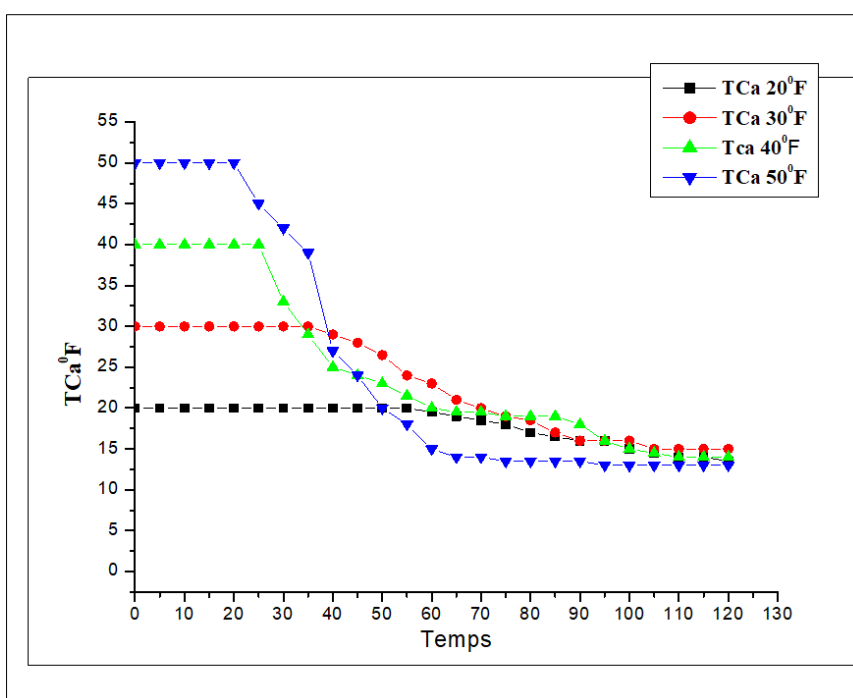


Figure 4 Evolution of the Ca^{2+} concentration of pure calcium-carbonate solutions at different concentrations

It can be seen that during the phase of the pH increase, no variation of the Ca^{2+} concentration is noted, which could be explained by the fact that this zone corresponds to the undersaturation zone where $[CO_3^{2-}].[Ca^{2+}] < K_s$, when the solubility product is exceeded, which coincides with the pH drop ($[CO_3^{2-}].[Ca^{2+}] > K_s$), the Ca^{2+} concentration of the TCa 500 F solution shows a drop at $t_g = 30$ mn which progresses to a limit value beyond which there is no variation of the Ca^{2+} concentration, then that of TCa 400 F at $t_g = 35$ mn, followed by the TCa 300 F at $t_g = 40$ mn and finally the TCa 200 F solution at $t_g = 60$ mn. This proves that calcium hardness has a considerable influence on the germination time as stated [8].

4. Conclusion

In this study, the LCGE setup was used to determine the germination time of different pure calcium-carbonate solutions at various concentrations. Thus, with regard to the geological and hydrogeological characteristics of the Tahoua region where the problem of scaling is frequently encountered, controlled degassing method can be a durable and less expensive solution to solve this problem. This method showed also that, the calcium hardness has a considerable influence on the germination time and that this parameter must be taken into account in the study of the precipitation kinetics of $CaCO_3$.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that they have no competing interests.

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