Journal of Open Technologies in Geophysics

RESEARCH ARTICLE

Water Saturation Calculation Using Archie's Equation for Shally Sand Formation : Case Study from Talang Akar Non Marine Formation, North West Java

Meutia Fitri Hasan[1]*

[1]Universitas Sriwijaya, Jalan Palembang-Prabumulih, KM 32 Inderalaya,Kabupaten Ogan Ilir, Sumater Selatan

***Corresponding Author:**
Meutia Fitri Hasan

Keywords:
Water saturation
Archie
Shally Sand
Talang Akar Non Marine

Citation:
Hasan, M. F. (2025). Water Saturation Calculation Using Archie's Equation for Shally Sand Formation : Case Study from Talang Akar Non Marine Formation, North West Java. *Journal of Open Technologies in Geophysics, 1(1), 1-7.*

Received 11 December 2025
Accepted 24 December 2025

Abstract Water saturation is one of the physical parameters of reservoir rocks that is important in determining the volumetric reserves of oil and gas fields. Several factors, including rock and fluid properties, also affect the diversity of water saturation values in reservoir rocks. One of the oldest methods, still used today, for determining Water Saturation values is the Archie method, which is based on the relationship between porosity, resistivity, and saturation. However, because reservoir rocks are heterogeneous, there are three (3) parameters that reflect rock characteristics: a (tortuosity factor), m (cementation exponent), and n (saturation exponent). Most previous studies of the shally sand lithology of the Talang Akar Formation calculate water saturation using the Simandoux or Indonesian Equation, but even those equations still use *a*, *m*, and *n* parameters in their formulas. Most previous studies do not provide detailed information on how they calculate water saturation and just jump straight to the results; meanwhile, those three parameters are important to define. The purpose of this study is to determine the Archie parameters *a*, *m*, and *n* in a well with shally sand lithology of the Lower Talang Akar Formation, and verify whether the water saturation value with the Archie equation is valid when applied to the well. The data used was obtained from the "Jeruk-2" well, in the form of well logs and core data (Routine Core Analysis and Special Core Analysis). As a result, it is found that the *a* and *m* values from the Jeruk-2 well were 1.47 and 1.81. The parameter *n* cannot be calculated because rock resistivity values at 100% brine saturation (*Ro*) are unavailable. Therefore, *n* value of 2 is used, as reported in the literature. The calculation results using the Archie formula indicate that the water saturation in the Zone of Interest "Jeruk-2" ranges from 0.22 to 1.00. The results of this calculation are verified with the water saturation value from SCAL data, giving a correlation coefficient of 0.79. This shows that for shally sand lithology of the Talang Akar Non Marine Formation around the Jeruk-2 well, the Archie equation can be used to calculate water saturation using the Archie parameters a = 1.47, m = 1.81, and n = 2. However, it is still recommended to calculate the Archie parameters for each well and formation to get more accurate results.

Abstrak *Saturasi air merupakan salah satu parameter fisik batuan reservoir yang cukup penting dalam penentuan cadangan volumetric lapangan migas. Beberapa factor dari sifat geologis batuan dan sifat fisik fluida turut mempengaruhi keberagaman nilai saturasi air batuan reservoir. Salah satu metode tertua dan masih digunakan sampai saat ini dalam menentukan nilai Saturasi Air adalah dengan metoda Archie, yang berdasarkan hubungan antara porositas, resistivitas dan saturasi. Namun karena batuan reservoir bersifat heterogen, maka terdapat tiga (3) parameter yang mencerminkan karakteristik batuan tersebut yaitu* a *(turtuosity factor),* m *(cementation exponent) dan* n

(saturation exponent). Mayoritas peneliti terdahulu menghitung saturasi air pada litologi Shally Sand dengan metoda Simandoux atau Indonesia, namun kedua metoda tersebut tetap membutuhkan nilai a, m dan n untuk melakukan perhitungan. Lalu tidak banyak studi yang membahas dengan detail cara menghitung saturasi air pada tiap sumur, sedangkan tiap komponen parameter perhitungan tersebut penting untuk dijelaskan. Tujuan studi ini adalah menentukan parameter Archie a, m dan n pada sumur dengan litologi shally sand Formasi Lower Talang Akar, dan memverifikasi apakah nilai saturasi air dengan persamaan Archie valid diaplikasikan pada sumur tersebut. Data yang digunakan berasal dari sumur "Jeruk-2",dengan kelengkapan data berupa log sumur dan data inti bor (Routine Core Analysis dan Special Core Analysis). Dari hasil penelitian, didapatkan bahwa nilai a dan m dari sumur "Jeruk-2" masing masing 1,47 dan 1,81. Untuk nilai parameter n tidak bisa dihitung karena ketiadaan nilai resistivitas batuan saat tersaturasi 100% air brine (Ro), sehingga digunakan nilai n sama dengan 2 mengikuti literatur. Hasil perhitungan dengan rumus Archie didapatkan bahwa nilai saturasi air di Zone of Interest "Jeruk-2" berkisar antara 0,22-1,00. Hasil perhitungan ini diverifikasi dengan nilai saturasi air dari data SCAL dan didapat koefisien korelasi sebesar 0,79. Hal ini menunjukkan bahwa pada litologi shally sand Formasi Talang Akar Non Marine area sekitas sumur Jeruk-2, persamaan Archie dapat digunakan untuk menghitung saturasi air dengan menggunakan parameter archie a= 1,47, m= 1,81 dan n=2. Namun tetap disarankan untuk menghitung parameter Archie masing masing sumur dan formasi untuk mendapatkan hasil yang lebih akurat.

1. Introduction

To obtain the exact value of Original Oil In Place, knowledge about the physical properties of reservoir rock is mandatory. Those properties are porosity, water saturation, and permeability. Not only is it necessary to determine the amount of hydrocarbon accumulation in the reservoir, but it is also necessary to know the rock properties to determine the appropriate stimulation for the well. For example, knowing which area has low saturation water, high hydrocarbon content, but low permeability, enabled us to still perform hydraulic fracturing in the reservoir (Pamungkas, 2025). Many water saturation formulas are made to determine the Sw value from well log. The most notable one is the Archie Equation (Eq. 1), found in 1942. Since Archie's equation was built for clean sand formation, it is rarely used in shally sand formation without some modification. Then Simandoux made some modifications in 1963 by adding the Volume of Shale (VShale) and Resistivity Shale (RS) to the previous formula, based on laboratory study. Poupon-Leveaux made the Indonesia Water Saturation to determine water saturation in laminated shally formations, based on field observation in Indonesia (Shedid & Mohamed, 2017).

Simandoux and Indonesian equation have something in common. They all need porosity, resistivity of water, true resistivity, and Archie's parameter, such as a (tortuosity), m (cementation exponent), and n (saturation exponent). Not so many publications dig deeper into those three elements. Most of the time, students only use general numbers like a=0.81, m=1.7, n=2 for sandstone, a=1, $m = n$=2 for limestone (Acosta & Z., 2017). Actually, those numbers are supposed to differ between rock types (Mohamad & Hamada, 2017). The value of m and n can be obtained by plotting core porosity (ϕ) as the axis and formation factor (F) as ordinate. Most petrophysicists follow Asquith's (Table 1) guide to determine the numbers $a, m,$ and n. This paper will delve deeper into the literature on how to determine each of those parameters.

Mabrouk & Soliman (2015) made a resume on his publication about many ways to define the number of F. All of the formulas stated by the previous study calculating F by inputting the porosity. Several approaches to calculate the number of F for sandstone are summarized in Table 2.

Although some papers have been published on how to define the Archie parameter for determining saturation water, few have been published in the Indonesian area. Most of scientists prefer using the Simandoux or Indonesian Equation, which is more suitable for the Shally Sand Reservoir. The hypothesis of this paper is

that Archie Equation is still relevant, if parameters a, m, and n are calculated thoroughly and Special Core Analysis (SCAL) data is available.

Table 1. Different coefficient and exponent to calculate saturation of water, modified from Asquith *(Acosta & Z., 2017)*

a=tortuosity factor	m=cementation exponent	Comment
1.0	2.0	Carbonates
0.81	2.0	Consolidated Sandstone
0.62	2.15	Unconsolidated Sands (Humble Formula)
1.45	1.54	Average Sands (Carothers, 1968)
1.65	1.33	Shaly Sands (Carothers, 1968)
1.45	1.70	Calcareous Sand (Carothers, 1968)
0.85	2.14	Carbonates (Carothers, 1968)
2.45	1.08	Pliocene Sands, Southern California (Carothers and Porter, 1970)
1.97	1.29	Miocene Sands, Texas-Louisiana Gulf Coast (Carothers and Porter, 1970)
1.0	$\emptyset^{2.05-\emptyset}$	Clean Granular Formation (Sethi, 1979)

Table 2 . Formation factor (F) formula as function of porosity (Modified from Mabrouk and Soliman, 2013)

Formula to calculate formation factor	Conditions
$F = 0.81/\emptyset^2$	Consolidated Sandstone
$F = 1.65/\emptyset^{1.33}$	For Shaly Sand (after Carothers, 1968)
$F = 1.13/\emptyset^{1.73}$	Timur et al (1972) from 1,833 sandstone sampels

2. Data and Methods

Determining value of a and m

Archie equation could be rearranged into this equation(Mohamad & Hamada, 2017),

$$Sw = \sqrt[n]{\frac{a\,R_w}{\emptyset^m R_t}} \qquad (1)$$

$$Ro = F\ x\ Rw \qquad (2)$$

The formation factor then rearranges and replaced by a, m and porosity (ϕ).

$$F = \frac{a}{\phi^m} \qquad (3)$$

$$\log F = \log a - m \log \emptyset \qquad (4)$$

By plotting the F value (ordinate) and porosity core (abscissa) in log scale, the parameter of a and m could be determined, the value of n in this study using value of 2, default for water-wet sandstone.

Those three parameters (a, m and n) then inserted into Archie equation for further Sw analysis,

$$Sw = \sqrt[n]{\frac{a\ R_w}{\emptyset^m R_t}}$$

Where Sw= Saturation of Water (fraction), n = saturation exponent, a = tortuosity, m= cementation exponent, Rw = Resistivity of formation water (Ω-m), ϕ=porosity (fraction), Rt = true formation resistivity (Ω-m).

The data used in this study consists of one well log and core data (Routine Core and SCAL data) from the field "Jeruk", located in Offshore North West Java (ONWJ). The study mainly focused on the Lower Talang Akar Interval, which consisted of shally sand lithology and part of the braided fluvial sandstone facies.
The availability of the data is shown in Table 3. Methodology in this paper follows those numbers.

1. Data Preparation. The minimum data needed to conduct this study are well log data and routine core data for calculating the Sw value, and SCAL data to verify the method's validity. From this step, only one well meets the requirement, "Jeruk-2".
2. Determine the value of Archie parameters a, m, and n. There are two choices for this step. The first one is to follow previous studies, such as Asquith (1980), which seems easier but might not be compatible with our study area. Or try to find the value by plotting the data manually. For this step, it was decided that the a and m parameters will be determined by plotting the F value (ordinate) and porosity core (abscissa) (Mohamad & Hamada, 2017). Meanwhile, the n parameter will use n value of 2, the default value for water-wet sandstone (Mohamad & Hamada, 2017).
3. Calculate Sw using the Archie equation. The parameters a, m, and n are those obtained in step two.
4. Verification. The result of step three then verified by SCAL data. If the coefficient of correlation is close to 1, the Archie formula can be considered valid for predicting water saturation in "Jeruk-2."

Table 3 . Data availability in "Jeruk-2" well

Data Availability	Jeruk-2
CALI	√
GR	√
SGR	√
SP	√
ILD	√
SFLU	
LLD	
LLS	
MSFL	√
NPHI	√
RHOB	√
DRHO	√
PEF	√
DT	√
Routine Core	√
Special Core Analysis	√

3. Results and Discussion

3.1 Results

Plot of logarithmic F against ϕ giving a and m value. Value of F in "Jeruk-2" is processed by petrophysical analysis software using value of resistivity log, temperature log and porosity log. Porosity log in this paper calculates with neutron density formula, and verified by routine core data.

From plot of F vs porosity (Figure 1), known that value of a is 1,47 and m is 1,81, normal value for sand like in the literature. Since value of n is unable to obtain due to lack of Ro data, value of n equals to 2 is used.

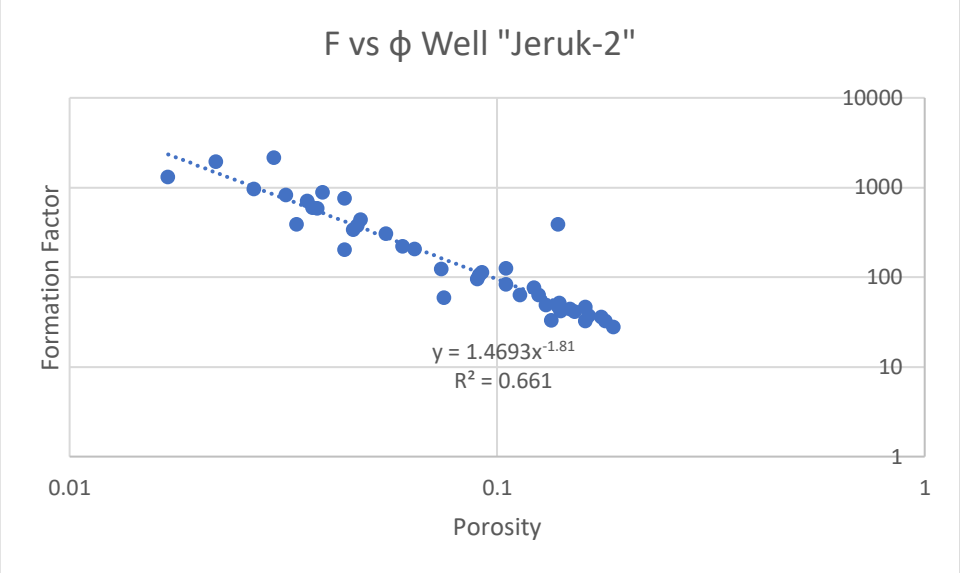

Figure 1. Plot of Formation Factor vs Porosity in log scale of well "Jeruk-2", shows that archie parameter a (tortuosity) is 1,47, and m (cementation exponent) is 1,81.

Inserted the value of a 1,47, m 1,81 and n 2, the saturation equation becomes.

$$Sw = \sqrt[2]{\frac{1{,}47\ R_w}{\emptyset^{1{,}81} R_t}}$$

The value of Rw calculated from SP log by using petrophysical analysis software, with mean of Rw 0,03 Ω-m. Rt value derived from ILD log. After calculate the water saturation using Archie Equation, we verified the result using SCAL data. SCAL (Special Core Analysis) is a test conducted on core sample, to measure water saturation in different condition. From the result, out of six points of SCAL data, one data missed far from prediction and giving the coefficient correlation of 0,79 (Figure 2 and 3).

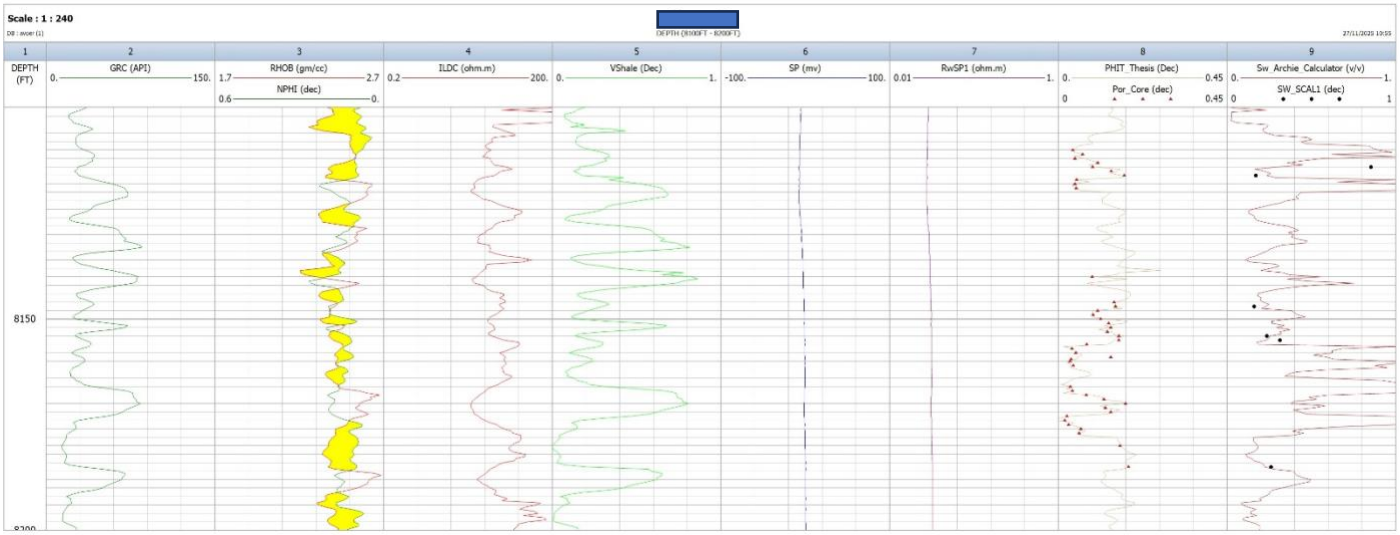

Figure 2 . Detail of well log data and water saturation prediction di well "Jeruk-2". 5 of 6 point of SCAL data has similar value of water saturation with Archie *Sw* prediction log.

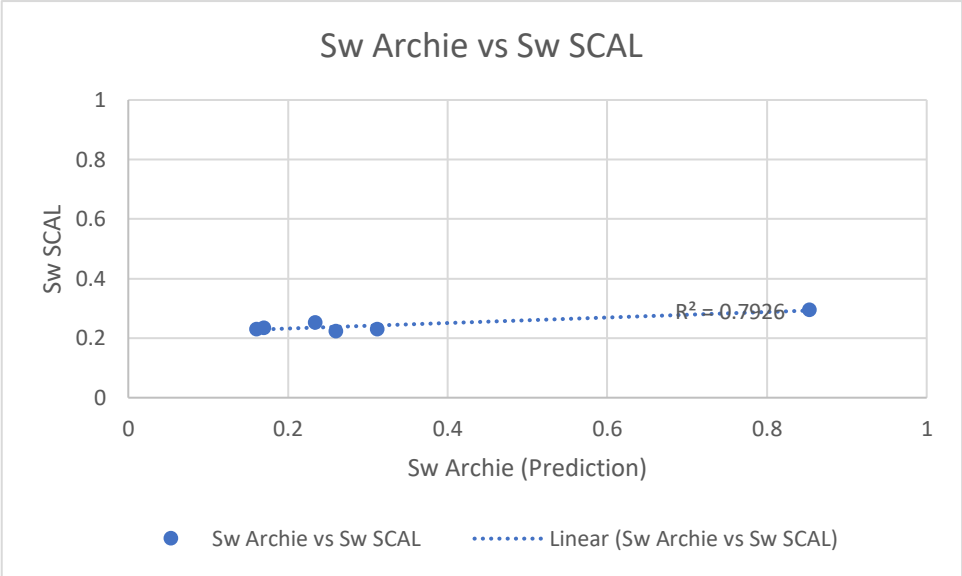

Figure 3 Comparison between water saturation value from SCAL data (y axis) and prediction value with Archie method (x axis). Only one data value missed the prediction of result (*Sw* SCAL 0,2 *Sw* Archie 0,8).

3.2 Discussion

A coefficient correlation of 0,79 between SCAL data and Archie method data indicates that the Archie equation remains a powerful tool to predict *Sw*. Even with a lithology that is not a clean sandstone, it could work out only if we understand each parameter and the data. Even just from one well log, it gives an optimistic outlook that if we carefully find the values $a, m,$ and n, the result will be accurate and not far from the SCAL data. But as a scientist, it's understandable that the study of water saturation is quite costly, since SCAL data is mandatory for the accuracy of the result. Maybe if more companies want to share the data from their inactive wells/fields, it will be beneficial for scientists in this area to make petrophysical studies more accurate.

4. Conclusions

From this study, it is concluded that in well "Jeruk-2", water saturation can be predicted using the Archie Equation with parameter values $a, m,$ and n of 1.47, 1.81, and 2, respectively. The coefficient of correlation

between the predicted *Sw* value and *Sw* from SCAL data is 0.79. For the next study, more data in the surrounding area within the same formation is needed to verify or improve the result.

Data Availability Statement

The data could not share openly due to restriction from company owner. The name of the well/field has been changed for educational purpose.

References

Chen, X., Kuang, L. C., & Sun, Z. C. (2002). Archie Parameter Determination By Analysis Of Saturation Data. *Petrophysics - the SPWLA Journal*, *43*(02).

E. R. Acosta and E. Rosales Z. (2017), Tortuosity and Cementation Factor Parameters: A Review on their Determinations. Researchgate.com.

Fadhil Sarhan Kadhim, Ariffin Samsuri, & Kamal, A. (2013, January 1). *A Review in Correlations between Cementation Factor and Carbonate Rocks Properties*. https://www.researchgate.net/publication/344746685

Hamada, G. M., & AL-Awad, M. N. (2001). Evaluating Uncertainty in Archie's Water Saturation Equation Parameters Determination Methods. *SPE Middle East Oil Show*. https://doi.org/10.2118/68083-ms

Hamada, G. M., Almajed, A. A., Okasha, T. M., & Algathe, A. A. (2012). Uncertainty analysis of Archie's parameters determination techniques in carbonate reservoirs. *Journal of Petroleum Exploration and Production Technology*, *3*(1), 1–10. https://doi.org/10.1007/s13202-012-0042-x

Mabrouk, W. M., & Soliman, K. S. (2014). A numerical technique for an accurate determination of formation resistivity factor using FR-RO overlays method. *Arabian Journal of Geosciences*, *8*(3), 1291–1297. https://doi.org/10.1007/s12517-014-1311-4

Mohamad, A. M., & Hamada, G. M. (2017). Determination techniques of Archie's parameters:a,mandnin heterogeneous reservoirs. *Journal of Geophysics and Engineering*, *14*(6), 1358–1367. https://doi.org/10.1088/1742-2140/aa805c

Pamungkas, Mohd. W. P. (2025). Hydraulic Fracturing Evaluation Of Well ZAA-011 Pangkalan Susu Field, North Sumatera. *Journal of Petroleum and Geothermal Technology*, *5*(2). https://doi.org/10.31315/jpgt.v5i2.13268

Shedid, A. S., & Mohamed, A. S. (2017). Analysis and field applications of water saturation models in shaly reservoirs. *Journal of Petroleum and Gas Engineering*, *8*(10), 111–122. https://doi.org/10.5897/jpge2017.0270