Study on shallow borehole Water blowout genesis based on geo-chemical properties from affected dug wells water

D B Dharma¹, S Rizal¹, M Umar¹, I Iskandar², Devianti³, R Idroes⁴,⁵,⁶*

¹Graduate School of Mathematics and Applied Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
²Earth Resources Exploration Research Group, Faculty of Mining and Petroleum Engineering, Institut Teknologi Bandung, Bandung 40132, Indonesia
³Agricultural Technology Department, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
⁴Energy and Mineral Resources Agency of Aceh Province, Banda Aceh 23114, Indonesia
⁵Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia

E-mail: rinaldi.idroes@unsyiah.ac.id

Abstract. This present study aimed to investigate the shallow borehole water blowout genesis based on geochemical properties from affected dug Well. A geochemical study was performed on dug well samples at the local community houses, namely SG-01, SG-02, SG-03, located around the blowout areas. The results showed that those three respective samples clustered onto two groups of water types, namely calcium bicarbonate in SG-01 and SG-02 and mixed types for SG-03, respectively. Moreover, the dissolved metal analysis did not show high concentration anomalies, whilst cation concentrations of the three samples are dominated by calcium, which is suspected from the rock dissolution process. The dominant anion is bicarbonate for SG-01 and SG-02, while the SG-03 sample is dominated by sulfate. The cross plot between the two isotope ratios with the global meteoric water line shows the isotope values of the SG-01 and SG-02 that are right on the global meteoric water line while SG-03 falls slightly above it.

1. Introduction
The Mediterranean plate, which passes through Sumatra Island, causes a lot of volcanic activity in Aceh Province. There are Jaboi [1], Seulawah Agam [2,3], and Bur Ni Geureudong [4] volcano sites, which are found in this area [5]. The volcano activity gives a force to underground elements such as groundwater, mud, and gases. The pressure pushes the elements to the surface through a cavity and appears as natural phenomena such as hot spring [6,7], fumarole [8], and mudflow [9]. A mapping of the geo-cavity [10] is necessary, particularly in mine drilling activity. The lack of this information cause of some mine disaster such as water blowout [11]. The Shallow borehole water blowout mixed with gas occurred in the Village of Tanjong Menje, Tanah Jambo Aye Subdistrict, North Aceh District, on Wednesday (23/01/2019), when one of the residents drilled a borehole in his chili garden yard.
the drilling reaches a depth of 20 meters, a gas-pressurized mixed mud occurs, which reaches a height of 20 meters. The blowout occurred around 09.00 AM West Indonesian Time, by late afternoon, the pressure from the burst reduced and stopped by itself. The blowout caused garden plants, road access, and residents’ houses around the blowout point to be covered in mud. Several communities dug wells in the vicinity also emitted gas bubbles with little pressure.

The location of the blowout point is the Working Area of PT. Pertamina Hulu Energi North Sumatera B (NSB) which is part of the North Sumatra Basin and is known as a sedimentary basin that has an 'overpressure'. Research conducted by Hutasoit [12] and several studies has shown the presence of 'overpressure' in this basin. The blowout location is right above the Rayeu-C1 and Rayeu-C2 oil and gas fields, where there are also anticline geological structures (Figure 1). It is feared that the gas blowout originates from gas seepage in the Rayeu field's reservoir, which can last a long time. To determine the source of water mixed with mud and methane gas, whether it comes from shallow gas deposits (biogenic) or comes from the seepage of the reservoir below it (thermogenic), a geochemical study including metal and stable isotope analysis needed to be done.

In finding reliable data and a graphical plot, an analysis method must be accurate. There are several methods which are recommended, that are ICP-OES, UV-Vis Spectrophotometer [8,13], ICP-AES, ICP-MS [14], Laser-Induced Breakdown Spectroscopy [15–17] and Ion Chromatography [18] for metal analysis, and Elemental Analyzer-Isotope Ratio Mass Spectrophotometry [19] and Laser Absorption Spectroscopy [20] for isotope analysis. In this study, the metal and isotope analysis were carried out on the water from dug wells in people's homes whose well water was affected by the blowout, which has a hydraulic relationship with the blowout point.
2. Methods and Materials

2.1. Geological and Hydrogeological Setting of the Study Area

Most of the sedimentary basins in western Indonesia, including the North Sumatra Basin, where the study area locates, have similar basin development histories and are well known as a highly overpressured basin. Overpressured strata are commonly encountered in the post-rift sequence because it is dominated by fine-grained sediments of low permeability [12]. The surface deposits of the study area are coastal and fluvial unnamed superficial deposits. The morphology of this area belongs to the morphology of the coastal alluvial plain, unfolded, and gently inclined strata. Lithology is in the form of gravel, sand, partly semi consolidated and mud. The permeability is medium to high [21].

The study area in the northern part of the Lhokseumawe Groundwater Basin locates at a limited area of artesian flow and water encroachment. The hydrogeological condition of the study area, according to Sutrisno [22], is included in the aquifer group in which has intergranular flow, extensive moderately productive aquifers, multi-layer aquifers of flow to moderate transmissivity, water table or piezometric head of groundwater near or above land surface, and wells generally yield less than 5 liters/sec.

2.2. Water Sampling and Field Data Measurement.

The collection of dug wells water samples for chemical and stable isotope analyses was performed on 31st January 2019, a week after the blowout. The physical properties of dug wells water, such as temperature (T), electrical conductivity (EC), and pH, were determined in the field during sampling activities as shown in Table 1.

| Sample | T °C | EC (µS/cm) | pH | Remarks |
|--------|------|------------|----|---------|
| SG-01  | 26.9 | 486        | 6.8| At the dug well, there was a roar and smelled methane gas. The measurement results, methane gas above the threshold. H₂S and CO gases that are toxic are not detected. Measurement of physical parameters of well water, color: brownish (very cloudy), odor: smelly |
| SG-02  | 26.9 | 449        | 6.9| Methane gas has not been detected, and there are no gas bubbles anymore. Measurement of physical parameters of well water, color: clear yellowish, odor: odorless |
| SG-03  | 27.0 | 700        | 6.9| There are no gas bubbles, but the well water becomes oily. Measurement of physical parameters of well water, color: brownish yellow, odor: odorless |

2.3. Instruments

Water samples were put in a polyethylene bottle. For isotope sampling of stable isotopes, $^{13}$C, and for the cation and anion analyses, no acidification process was needed. There should be no bubble or a minor head-space (less than 50% of the sample volume) in a tightly capped bottle. Inductively-Coupled Plasma Mass Spectrometry (ICP-MS) was used to analyze minor and trace elements in the water samples. Ion Chromatography was performed to analyze for Na⁺, K⁺, Ca²⁺, Mg²⁺, SO₄²⁻ and Cl⁻, while a titration method was performed to analyze total HCO₃⁻ and CO₃²⁻. Gas Chromatography – Isotope Ratio Mass Spectrometry analytical method is used to analyses δ$^{13}$C/$^{12}$C, and water isotope analytical method is used to δ$^{18}$O/$^{16}$O and δ²H/$^{1}$H.
3. Result and Discussion

The chemical nature of dugwells water studied is shown in the Piper diagram in Figure 3a, and stiff pattern Figure 3b. The composition of major ions (Na, K, Ca, Mg, SO₄²⁻, HCO₃⁻, and Cl⁻) of the three samples show two groups of water types, namely the type of calcium bicarbonate in samples SG-01 and SG-02, the type of mixture for samples SG-03. The dissolved metal analysis did not show high concentration anomalies (Table 2), which indicates no related to thermogenic sources. The cation concentration of the three samples was dominated by calcium, which was thought to have originated from the rock dissolving process.

![Figure 3. Piper diagram for dugwells water surrounding blowout point (a), Analysis of dugwells water represented by Stiff pattern (b).](image)

The dominant anion is bicarbonate for SG-01 and SG-02, while the SG-03 sample is dominated by sulfate. Even so, the bicarbonate composition in the SG-03 sample remains high. The dominance of bicarbonate is thought to be due to the influence of rocks and meteoric water.

| Sample  | Li  | B   | As  | F   | Cl  |
|--------|-----|-----|-----|-----|-----|
| SG-01  | 0.002 | 0.065 | 0.011 | 0.14 | 20.54 |
| SG-02  | 0.004 | 0.039 | 0.005 | 0.02 | 18.11 |
| SG-03  | n.d  | 0.03  | 0.01  | n.d  | 41.47 |
Figure 4. $\delta^2$H and $\delta^{18}$O values from dugwells water surrounding the blowout point.

The isotope data for water ($\delta^{18}O/^{16}O$ and $\delta^2H/^{1}H$) have relatively light isotope ratios. A cross plot between these two isotope ratios, and the global meteoric water line in Figure 4 shows the exact isotope values of samples SG-01 and SG-02 in the global meteoric waterline. The SG-03 sample fell slightly above the global meteoric waterline (lighter oxygen ratio), indicating a carbon dioxide reaction as shown in Figure 5.

Figure 5. Variation in $\delta^{13}C_{CO2}$ levels of different origins.
Tabel 3. The relative concentration of δ¹³ C/¹²C in dug wells water samples.

| Sample | Species | δ¹³ C/¹²C (‰) |
|--------|---------|---------------|
| SG-01  | CO₂     | -13,573       |
| SG-02  | CO₂     | -12,179       |
| SG-03  | CO₂     | -17,895       |

The composition of δ¹³ C in various conditions shows large variations due to the impact of different environmental parameters are summarized in Figure 5 [23]. Analysis of the δ¹³ C/¹²C isotope of the three dug wells water samples showed ratios ranging from -12 ‰ to -18 ‰. The isotope ratio δ¹³ C/¹²C in this range characterizes the source originating from groundwater, either DIC (dissolved inorganic carbon) or DOC (dissolved organic carbon). Samples SG-01 and SG-02 have a source originating from DIC groundwater, while for samples SG-03 comes from DOC groundwater. These samples do not indicate a thermogenic effect of the hydrocarbons.

4. Conclusion
Based on the results of the analysis of the three samples (SG-01, SG-02, and SG-03), it is known that the groundwater samples originate close to the surface. There is no thermal influence on the formation and source of groundwater. The high concentration of bicarbonate indicates the influence of groundwater and meteoric water, which is also supported by the relatively light isotope ratios of δ¹⁸O/¹⁶O and δ²H/¹H. Methane gas mixed with water comes from shallow gas deposits or swamp gas (biogenic gas), not from thermogenic gas in the oil and natural gas reservoir.

References

[1] Cesarian D P, Abir I A and Isa M 2018 Comparison of In-Situ Temperature and Satellite Retrieved Temperature in Determining Geothermal Potential in Jaboi Field, Sabang J. Phys. Conf. Ser. 1116 032008
[2] Idroes R, Yusuf M, Alatas M, Subhan, Lala A, Saiful, Suhendra R, Idroes G M and Marwan 2018 Geochemistry of hot springs in the Ie Seu’um hydrothermal areas at Aceh Besar district, Indonesia IOP Conf. Ser. Mater. Sci. Eng. 334 012002
[3] Nuraskin C, Marlina, Idroes R, Soraya C and Djufri 2020 Identification of secondary metabolite of laban leaf extract (Vitex pinnata l) from geothermal areas and non-geothermal of agam mountains in Aceh Besar, Aceh province, Indonesia Rasayan J. Chem. 13 18–23
[4] Putri D R, Nanda M, Rizal S, Idroes R and Ismail N 2019 Interpretation of gravity satellite data to delineate structural features connected to geothermal resources at Bur Ni Geureudong geothermal field IOP Conf. Ser. Earth Environ. Sci. 364 012003
[5] Marwan, Yanis M, Idroes R and Ismail N 2019 2D inversion and static shift of MT and TEM data for imaging the geothermal resources of Seulawah Agam Volcano, Indonesia Int. J. GEOMATE 17 173–80
[6] Idroes R, Yusuf M, Alatas M, Subhan, Lala A, Muslem, Suhendra R, Idroes G M, Suhendrayatna, Marwan and Riza M 2019 Geochemistry of warm springs in the Ie Bróuk hydrothermal areas at Aceh Besar district IOP Conf. Ser. Mater. Sci. Eng. 523 012010
[7] Idroes R, Yusuf M, Alatas M, Subhan, Lala A, Muhammad, Suhendra R, Idroes G M and Marwan 2019 Geochemistry of Sulphate spring in the Ie Jue geothermal areas at Aceh Besar district, Indonesia IOP Conf. Ser. Mater. Sci. Eng. 523 012012
[8] Idroes R, Yusuf M, Saiful S, Alatas M, Subhan S, Lala A, Muslem M, Suhendra R, Idroes G M, Marwan M and Mahlia T M I 2019 Geochemistry Exploration and Geothermometry Application in the North Zone of Seulawah Agam, Aceh Besar District, Indonesia Energies 12 4442
[9] Prime N, Dufour F and Darve F 2014 Solid-fluid transition modelling in geomaterials and application to a mudflow interacting with an obstacle *Int. J. Numer. Anal. Methods Geomech.* **38** 1341–61

[10] Marwan, Syukri M, Idroes R and Ismail N 2019 Deep and Shallow Structures of Geothermal Seoulawah Agam Based on Electromagnetic and Magnetic Data *Int. J. GEOMATE* **16** 141–7

[11] Hadiyantina S and Ramdhan N 2018 The Emergency of Authority on the Supervision of Old Wells Mining Policy in Indonesia Proceedings of the 2018 International Conference on Energy and Mining Law (ICEML 2018) (Paris, France: Atlantis Press)

[12] Hutasoit L 2013 Overpressure Characteristics In Pertamina’s Area In The North Sumatra Basin *PROCEEDINGS, Indones. Pet. Assoc. Thirty-Sev* 2013

[13] Suhartono E, Thalib I, Aflanie I, Noor Z and Idroes R 2018 Study of Interaction between Cadmium and Bovine Serum Albumin with UV-Vis Spectroscopy Approach *IOP Conf. Ser. Mater. Sci. Eng.* **350** 12008

[14] Guo Q, Pang Z, Wang Y and Tian J 2017 Fluid geochemistry and geothermometry applications of the Kangding high-temperature geothermal system in eastern Himalayas *Appl. Geochemistry* **81** 63–75

[15] Lahna K, Idroes R, Idris N, Abdulmadjid S N, Kurniawan K H, Tjia M O, Pardede M and Kagawa K 2016 Formation and emission characteristics of CN molecules in laser induced low pressure He plasma and its applications to N analysis in coal and fossilization study *Appl. Opt.* **55** 1731

[16] Marpaung A M, Ramli M, Idroes R, Suyanto H, Lahna K, Abdulmadjid S N, Idris N, Pardede M, Hedwig R, Lie Z S, Kurniawan D P, Kurniawan K H, Lie T J, Tjia M O and Kagawa K 2016 A comparative study of emission efficiencies in low-pressure argon plasmas induced by picosecond and nanosecond Nd:YAG lasers *Jpn. J. Appl. Phys.* **55** 116101

[17] Pardede M, Jobiliong E, Lahna K, Idroes R, Suyanto H, Marpaung A M, Abdulmadjid S N, Idris N, Ramli M and Hedwig R 2019 The underlying physical process for the unusual spectral quality of double pulse laser spectroscopy in He gas *Anal. Chem.*

[18] Tassi F, Aguilera F, Darrah T, Vaselli O, Capaccioni B, Poreda R J and Delgado Huertas A 2010 Fluid geochemistry of hydrothermal systems in the Arica-Parinacota, Tarapacá and Antofagasta regions (northern Chile) *J. Volcanol. Geotherm. Res.* **192** 1–15

[19] Avşar Ö, Güleç N and Parlaktuna M 2013 Hydrogeochemical characterization and conceptual modeling of the Edremit geothermal field (NW Turkey) *J. Volcanol. Geotherm. Res.* **262** 68–79

[20] Wassenaar L I, Ahmad M, Aggarwal P, Van Duren M, Pöltenstein L, Araguas L and Kurttas T 2012 Worldwide proficiency test for routine analysis of δ2H and δ18O in water by isotope-ratio mass spectrometry and laser absorption spectroscopy *Rapid Commun. Mass Spectrom.* **26** 1641–8

[21] Keats W., Cameron N.R., Djunuddin A., Ghazali S.A., Harahap H., Kartawa W., Ngabito H., Rock N.M.S., Thompson S.J. W R 1981 *Geological Map of the Lhokseumawe Quadrangle, Sumatra* (Bandung, Indonesia)

[22] Soetrisno S. 1986 *Hydrogeological Map of Indonesia, Lhokseumawe and Simpang Ulim Sheet, Sumatra* (Bandung, Indonesia)

[23] Iskandar I, Dermawan F, Sianipar J, Suryantini and Notosiswoyo S 2018 Characteristic and Mixing Mechanisms of Thermal Fluid at the Tamponas Volcano, West Java, Using Hydrogeochemistry, Stable Isotope and 222Rn Analyses *Geosciences* **8** 103