Jurnal Pena Sains Vol. 5, No. 1, April 2018 p-ISSN: 2407-2311
e-ISSN: 2527-7634

ZEOLITE: STRUCTURE AND POTENTIAL IN AGRICULTURE

Riva Ismawati

Natural Science Education Study Program, University of Tidar
Magelang, 56116, Indonesia
rivaismawati@untidar.ac.id

Abstract

Zeolite is a hydrated aluminosilicate mineral with three-dimensional structure. The unique zeolite crystal structure makes zeolites have cation boundary properties, adsorption, molecular sieving, catalysts, capture and release of air molecules. Many studies in various fields including agriculture have been done by utilizing the properties of the zeolite. Indonesia has an abundant source of zeolite reserves and extensive agricultural areas, making it possible to apply zeolite research results to support sustainable agricultural activities. In this article will discuss the potential utilization of zeolite in agriculture based on the studies that have been done.

Keywords: ***Aluminosilicate, Agriculture, Zeolite*.**

Introduction

Zeolite mineral is a hydrated aluminosilicate included in tectosilicate type with three-dimensional shaped frame (Valdés, Pérez-Cordoves, & Díaz-García, 2006). Zeolite naturally formed millions of years ago from fine-grained pyroclastic material (tuff) Volkan. Areas in Indonesia found zeolite because many volcanoes that produce acidic Tuff and composed by cryolitic the finest glasses (Suwardi, 2009).

Natural zeolite has a composition that depend on the State of the hydrothermal environment, such as temperature, pressure, water vapor composition of ground water formation locations zeolite. The condition of a natural zeolite resulted in the location of the source have a different type of zeolite compositions from another location, although it has the same color and texture (Las & Zamroni, 2002).

The three-dimensional structure of Zeolite makes zeolites have a high surface area. This enables the zeolite gas molecules can absorb on the position of the water crystal. Adsorption ability of the zeolite is also determined by the charge and location of cations in zeolite cavities counterbalance (Las & Zamroni, 2002).

The nature of such unique zeolite allows its utilization in various fields, including agriculture. Development of promotional activities management of agriculture by using zeolite has long been conducted by private parties. However, its use has not been much noticed by farmers (Al-Jabri, 2009).

Intensive agriculture Activities along with the practice of the use and management of the unbalanced fertilizer has caused a decline in the quality of the soil. The population continues to grow causing food needs will also increase. Meanwhile, soil degradation is a major issue that needs immediate attention (Sangeetha & Baskar, 2016). The world's semi-arid land which is evident from the report of the Royal Commission of Agriculture (1928). Thus, the utilization of zeolite in agriculture have been considered very important.

Utilization of zeolite in fertilizing the plants had long been known. In the meantime, some research has been conducted to examine the potential other than zeolite which can be utilized in the field of agriculture. Development of the research potential of these little-known zeolites. Indonesia has abundant reserves of zeolite resources as well as the vast agricultural area. Thus, it may need to know the results of the research that has been done in an effort to improve the quality of zeolite in agriculture. This article will review of the structure and properties of zeolites, zeolite resources in Indonesia as well as some potential in the agriculture.

Research Methods

The method of writing is the study of the literature. A variety of literature about the utilization of zeolite in agriculture collected. The information obtained was compiled based on the results of the study are obtained.

Results and Discussions

Structure and properties of Zeolites.

Zeolite is a aluminosilicate type tectosilicate, where hydrated tetrahedral SiO4 form the super cage of three dimensions. A number of the atoms in the structure of the zeolite was replaced by Al atoms. Consequently, the negatively charged zeolite structure derived from the difference between the tetrahedral structure TO_4, with T = Si or Al. Negative charge on an ion balanced by zeolite the opposite charge. Offsetting these cations are usually alkali and alkaline earth cations and can be replaced by other cations. Therefore, zeolite can be used as an ion exchanger (Valdés et al., 2006).

Zeolite has the empirical formula:

$$M_{2/n}O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$$

where M is an alkali or an alkaline earth element, n is the valence charge element, x is the number of molecules of SiO2 from 2-10, and y is the number of molecules of H2O of 2-7

The open framework structure zeolites, quartz and feldspar isn't like that have a structure of solid meetings and shutdown (Mumpton, 1985). The structure of the Zeolite Framework served as in **Figure 1**. The open structure of the zeolite to zeolite allows in can catch and removing the water is reversible and cation exchange extra framework without changing the structure of crystals.

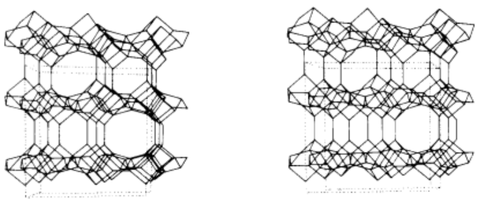

Figure 1. The structure of the Zeolite Framework types clinoptilolites

Cation exchange capacity (CEC) of the zeolite is basically a function of the number of Al that replaces the tetrahedral framework; the larger the number, the more Al extra framework cations necessary to neutralize the charge zeolite. Natural zeolite has the CEC from 2-4 meq/g, two times greater than the CEC bentonite. Unlike most of the non-crystallin ion exchanger resin, such as organic and inorganic aluminosilicate gel, crystalline zeolite frameworks have selectivity of ion. Clinoptilolite has a value of CEC are relatively small (2.25 meq/g), with high selectivity cations:

Cs >Rb> K >NH_4> Ba >Sr> Na> Ca> Fe> Al> Mg >Li (Mumpton, 1999).

Zeolite Properties associated with the structure. Utilization of natural zeolite in various fields, including agriculture should consider the properties of the zeolite, among which: (i) cation exchange, (ii) adsorption and filtration of the molecule catalyst, (iii), (iv) the arrest and release of water molecules, (v) biological reactivity (Mumpton, 1999).

The Source Location of the Zeolite in Indonesia

Experts estimate mineralogy natural zeolite derived from eruptions of the volcano that froze into volcanic rocks, sedimentary rocks, rocks metamorphosis. The rock then undergoes weathering caused by heating and cooling that occur in the pits of lava rocks basalt (traps rock) and the fine grain of sediment rocks are pyroclastic (tuff) (Sukaesih, 2014).

Based on geological, Indonesia could potentially generate large zeolite. Indonesia is in the region of a series of volcanoes ranging from Sumatra, Java, Nusa tenggara to Sulawesi. Various types of rocks volcano that produced, among others, in the form of smooth rocks of pyroclastic acidic Tuff and is composed of dacitic-rhyolite. TUF finely widespread following the path of the volcano that is partially or completely has undergone a process of revision into zeolite (Kusdarto, 2008).

Some types of zeolite chabazite clinoptilolite, among others, mordenite, fillipsite, and erionite. Zeolite rocks typically contain 50-95% of single zeolite. However, some types of zeolites can be found in the rocks mixed with dopants (Mumpton, 1999). The zeolite mineral found in Indonesia is generally dominated by clinoptilolite and mordenite.

Endapan zeolit di Indonesia tersebar di 20 Deposits of zeolites in Indonesia spread across 20 locations with a total of 447,490,160 tons of resources, such as in West Java province has reserves of 185,595,160 tons, the province of Lampung have backup 43.8 million tons, East Nusa Tenggara province have Backup 6,115,000 tons, West Sulawesi province has reserves of 26.4 million tons, South Sulawesi province has reserves of 169,880 tons, and the province of North Sumatra had 16.2 million tons of reserves as presented in table 1 (Kusdarto, 2008).

.

Table 1. Resource Location zeolite in Indonesia

No	Location	Province	Regency	Sub	Resources (tons)	Description
1	Pasir Gombong	Banten	Lebak	Bayah	123.000.000	The type of mineral (32.70%), mordenite clinoptilolite (30.89%). CEC values his range between 52 up to 67 meq/100 g
2	Nanggung	Jabar	Bogor	Nanggung	25.000.000	The form of mordenite and clinoptilolite
3	Desa Tunggilis	Jabar	Ciamis	Kalipucang	520.000	The value of the C.E. c: 184.08 meq/100 g
4	Bojong	Jabar	Sukabumi	Cikembar	24.151.000	Livestock feed
5	Gegerbitung	Jabar	Sukabumi	Gegerbitung	100.000.000	-
6	Cikandra	Jabar	Tasikmalaya	Cikalong	2.766.160	the form of mordenite clinoptilolite and, CEC 112,70-203,35 meq/100 g
7	Sindangkerta	Jabar	Tasikmalaya	Cipatujah	4.158.000	the form of mordenite clinoptilolite and 83,30, CEC-222,95 meq/100 g
8	Cibatuireng dan Karangmekar	Jabar	Tasikmalaya	Karangnunggal	6.000.000	The form of mordenite

No	Location	Province	Regency	Sub	Resources (tons)	Description
						clinoptilolite and 105,35, CEC-183,29
9	Desa Campangtiga	Lampung	Lampung Selatan	Kalianda	200.000	PT Mina Tama
10	Katibung	Lampung	Lampung Selatan	Katibung	2.000.000	The form of mordenite clinoptilolite and 85,26, CEC-174,64 meq/100 g
11	Pantai Tengor	Lampung	Tanggamus	Cukuh Balak	37.000.000	High levels of zeolite (clinoptilolite)
12	Desa Tengor	Lampung	Tanggamus	Cukuh Balak	4.600.000	Already been exploited, but had stopped more than 5 years
13	Desa Khekado	NTT	Ende	Ende	100.000	CEC 190.93 meq/100 g
14	Desa Maurole	NTT	Ende	Maukaro	525.000	Consists of mordenite, quartz, plagioclase
15	Aifua, Desa Ondorea	NTT	Ende	Nangapanda	3.990.000	Mordenite, minerals, quartz, clinoptilolite and plagioclase
16	Riasawa Barat, Desa Ondorea	NTT	Ende	Nangapanda	1.250.000	Minerals, mordenite clinoptilolite, CEC 168.13 meq/100 g
17	Riasawa Timur, Desa Ondorea	NTT	Ende	Nangapanda	250.000	Minerals, mordenite clinoptilolite, CEC 169.35 meq/100 g
18	Desa Seppong, Kec. Sendana	Sulbar	Majene	Sendana	26.400.000	CEC = meq 135.57 147.56 meq%-%
19	Desa malimongan	Sulsel	Bone	Salomeko	1.400.000	-
20	Sangkaropi-Medila	Sulsel	Tanatoraja	Sesean	168.480.000	Types of mordenite and heulandite, CEC 16,91-108,43 meq/100 g

Source: Balance of Non Metallic Mineral Resources National Year 2008 in Kusdarto, (2008).

The potential utilization of Zeolite in Agriculture

Increased efficiency of use of nitrogen. The use of dissolved N fertilizer is one of the main causes of water pollution of soil in farmland. Zeolite modified with a hexadecyltrimethylammonium, a cationic surfactant, to increase storage capacity of nitrate. Studies show that absorption of nitrates to the SMZ was increased while the amount of surfactant at the SMZ was increasing, while the slow release of nitrate can be reached (Li, 2003). In addition to increasing the efficiency of nitrogen fertilizers, zeolite can also reduce the release of nitrate with ammonium into nitrate inhibits nitrification (Perrin *et. al*., 1998).

An increase in the efficiency of the use of Phosphor. Zeolites have been used to control release fertilizer components. A charged ammonium zeolite has demonstrated its ability to enhance the dissolving phosphate minerals, which causes the absorption of phosphorus by plants increases. Studies conducted to examine the solubility and the exchange of cations in a mixture of phosphate rock and saturated clinoptilolite $NHCl_4^+/K^+$ indicates that phosphate rocks and zeolite mixture potentially provides a release slow fertilizer on plants through the dissolving reaction and ion exchange (Allen et al., 2001).

The influence of the presence of saturated potassium and ammonium clinoptilolite against phosphor availability in ferrosols has been investigated. The results showed that clinoptilolite saturated potassium and ammonium can increase the solubility while releasing the ions K^+ and $NH4^+$ into the ground. It will increase the growth of plants (Hua et al., 2006).

System slow off nutrients. Kithome et al. (1998) have demonstrated the ability of natural zeolite adsorbent as NH_4^+ and use it as fertilizer off the slow NH_4^+. Adsorption equilibrium of NH_4^+ reached on a span of 60 minutes with initial concentration of NH_4^+ 140.1 mg/L at pH 4 to 120 seconds for the initial concentration of NH_4^+ 840.6 mg/L at pH 7. Desorbs approaching perfect within 150 minutes for an initial concentration of NH_4^+ low and 200 minutes for the concentration of NH_4^+ . The number of NH_4^+ the absorption as well as desorption increased with increasing pH and concentration of the beginning of NH_4^+. These results demonstrate the ability of the zeolite in storing and releasing the NH_4^+.

Zeolites can also be combined with other materials as a composite system off the slow micronutrition. Ismawati dan Arryanto (2013) of using Chitosan composite zeolite as a freelance system slow ion Fe^{3+}. The more mass the slower zeolite ion Fe^{3+} released from the composite. Meanwhile, a growing number of times faster than Chitosan ion Fe^{3+} released from the composite.

System off slow herbicides. Zeolite, activated acid has the ability to adsorbs atrazine. Activation of zeolites against acid can increase the ability of the zeolite binds atrazine. However, damaging the structure of the zeolite, primarily zeolite-rich aluminum and Silicon are poor such as filipsit and chabazite. Clinoptilolite have the ability adsorbs herbicides atrazine is higher. Interactions involving electrostatic bonds followed the rate of two-order pseudo kinetic (Salvestrini et al., 2010).

Formula off slow 2.4-D combined with the mineral zeolite and bentonite modified by surfactant CTMA. An experiment was conducted to find out the potential formula off slow in controlling weeds as well as reduce herbicide leaching into the soil layer. The results showed that the slow-off formula can be used as weed control in sustainable agriculture (Shirvani et al., 2014).

Repair physical properties of soil. Zeolites have been reported can improve the physical properties of the soil. They can hold more than half of its weight. This is due to the high porosity of the Crystal structure of the zeolite. Water molecules in Zeolite Framework can be easily removed and in thecatch back without damaging the structure ofhis. Zeolitescan provide for the needs of water in a sustainable way. This led to savings of water needed for irrigation. Replacement planting media sand with zeolite can increases the availability of the water for plants of 50% (Voroney & Straaten, 1988).

Remediation of contaminated soil. Use of zeolite on heavy metal contaminated soils or radionuclide can lower levels of contaminants by effectively. This research very promising and requires extensive research (Ramesh et al., 2010). *Buffer soil pH.* Zeolite is not acidic and slightly alkaline but its use with fertilizer can help stabilize the pH level of the soil. Thus, it can reduce the need for the use of lime (Ramesh et al., 2010)

Conclussions and Discussions

Utilization of zeolite in agriculture requires an understanding of the structure and properties of zeolites. Integrated research is required to improve the quality of zeolite in Indonesia. In addition, the cooperation and partnership between the Government, entrepreneurs and farmers needed to develop local utilization of zeolite.

Reference

Al-Jabri. (2009). Peningkatan Produksi Tanaman Pangan dengan pembenah Tanah Zeolit. *Sinar Tani*.

Allen, E. R., Hossner, L. R., Ming, D. W., & Henninger, D. L. (2001). Solubility and cation exchange in phosphate rock and saturated clinoptilolite mixtures. *Soil Science Society of America Journal. Soil Science Society of America*, *57*(5), 1368–1374. https://doi.org/10.2138/rmg.2001.45.18

Hua, Q. X., Zhou, J. M., Wang, H. Y., Du, C. W., Chen, X. Q., & Li, J. Y. (2006). Effects of modified clinoptilolite on phosphorus mobilisation and potassium or ammonium release in Ferrosols. *Australian Journal of Soil Research*, *44*(3), 285–290. https://doi.org/10.1071/SR05118

Ismawati, R., & Arryanto, Y. (2013). *Komposit Kitosan-Zeolit sebagai Sistem Lepas Lambat Besi (III).* (Doctoral dissertation, Universitas Gadjah Mada).

Kithome, M., Paul, J. W., Lavkulich, L. M., & Bomke, A. A. (1998). Kinetics of Ammonium Adsorption and Desorption by the Natural Zeolite Clinoptilolite. *Soil Science Society of America Journal*, *62*(3), 622. https://doi.org/10.2136/sssaj1998.03615995006200030011x

Kusdarto. (2008). Potensi Zeolit Di Indonesia. *Jurnal Zeolit Indonesia*, *7*(1411–6723), 2. https://doi.org/http://journals.itb.ac.id/index.php/jzi/article/download/1714/1009.

Las, T., & Zamroni, H. (2002). Application of Zeolite in Industries and Environments. *Jurnal Zeolit*

Indonesia, 23–30. Retrieved from http://journals.itb.ac.id/index.php/jzi/article/view/1646

Li, Z. (2003). Use of surfactant-modified zeolite as fertilizer carriers to control nitrate release. *Microporous and Mesoporous Materials*, *61*(1–3), 181–188. https://doi.org/10.1016/S1387-1811(03)00366-4

Mumpton, F. A. (1999). La roca magica: Uses of natural zeolites in agriculture and industry. *Proceedings of the National Academy of Sciences*, *96*(7), 3463–3470. https://doi.org/10.1073/pnas.96.7.3463

Mumpton, F. A.. (1985). Using Zeolite in Agriculture. *Innovative Biological Technologies for Lesser Developed Countries*, Washington.

Perrin, T. S., Boettinger, J. L., Drost, D. T., & Norton, J. M. (1998). Decreasing nitrogen leaching from sandy soil with ammonium-loaded clinoptilolite. *Journal of environmental quality*, *27*(3), 656-663.

Ramesh, K., Biswas, A. K., Somasundaram, J., & Rao, A. S. (2010). Nanoporous zeolites in farming: Current status and issues ahead. *Current Science*.

Royal Commision of Agriculture. (1928). *Report of the Royal Commission of Agriculture in India*, 755.

Salvestrini, S., Sagliano, P., Iovino, P., Capasso, S., & Colella, C. (2010). Atrazine adsorption by acid-activated zeolite-rich tuffs. *Applied Clay Science*, *49*(3), 330–335. https://doi.org/10.1016/j.clay.2010.04.008

Sangeetha, C., & Baskar, P. (2016). Zeolite and its potential uses in agriculture : A critical review. *Agricultural Reviews*, (of). https://doi.org/10.18805/ar.v0iof.9627

Shirvani, M., Farajollahi, E., Bakhtiari, S., & Ogunseitan, O. A. (2014). Mobility and efficacy of 2,4-D herbicide from slow-release delivery systems based on organo-zeolite and organo-bentonite complexes. *Journal of Environmental Science and Health - Part B Pesticides, Food Contaminants, and Agricultural Wastes*, *49*(4), 255–262. https://doi.org/10.1080/03601234.2014.868275

Sukaesih. (2014). *Kualitas Zeolit di Kabupaten Ende Provinsi Nusa Tenggara Timur*. Makalah dipresentasikan pada Seminar Nasional Fakultas Teknik Geologi, Universitas Padjajaran.

Suwardi. (2009). Teknik Aplikasi Zeolit di Bidang Pertanian sebagai Bahan Pembenah Tanah. *Journal of Indonesia Zeolites*, *8*(1), 33–38.

Valdés, M. G., Pérez-Cordoves, A. I., & Díaz-García, M. E. (2006). Zeolites and zeolite-based materials in analytical chemistry. *TrAC - Trends in Analytical Chemistry*. https://doi.org/10.1016/j.trac.2005.04.016

Voroney, R. P., & Van Straaten, P. (1988). Use of natural zeolites in sand root zones for putting greens. *Greenmaster Magazine*, *8*, 19.