# Chemical Properties and Potential Use in Agriculture of Leonardite from Different Sources in Thailand

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## Abstract

Several types of leonardite from various deposits in Thailand; Mae Moh, Chiang Muan and Lee mine, were examined as potential organic materials for agriculture. Chemical compositions of leonardite varied from place to place. The pH values of most leonardite samples were very extremely low (1.84-2.55, very acidic). Plant nutrients elements contained in leonardite were quite high (N, K, S, Ca, Mg, Fe, Zn and Mn) except for phosphorus. Leonardite from Mae Moh and Lee mine contained quite high amount of humic acid (34.73-61.58 and 39.19-85.05%, respectively). With high nutrients and humic acid content, leonardite could be used to improve organic matter, humic acid and some plant nutrient levels in the soils. However, raising the P content and the pH value of leonardite by rock phosphate and liming materials to the suitable range for crop production should be considered before soil application.

**Keywords**: Leonardite plant nutrients chemical properties

## Introduction

Leonardite is a natural organic material through the decomposition process for more than 70 million years. This organic material is considered as an oxidized form of lignite that occur at shallow depths, overlying more compact coal in a coal mine (Stevenson 1979). Leonardite cannot be used as fuel because of its low heating content. Although undesirable as fuel, its high content of humic acid (HA) (which ranges from 30 to 80%), may make it useful as a soil amendment and organic fertilizer. Humic and fulvic acids are usually used in agricultural production and are widely known as having agronomic potential (Ece et al., 2007). Humic

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substances (humic and fulvic acids), the major components of soil organic matter, are mostly used to eliminate adverse effects of chemical fertilizers and decrease soil pH (Chen and Aviad, 1990; Akıncı et al., 2009; Katkat et al., 2009). Humic substances constitute an important fraction of soil organic matter, have a positive influence on soil fertility and the physical integrity of soil, and increase the availability of nutrients (Stevenson, 1979; Akinremi et al., 2000). There are economic deposits of humate-rich material in Arkansas, Florida, Louisiana, New York, North Dakota, Michigan, Minnesota, Texas, and Wyoming according to Burdick (1965). There are several sources of leonardite in Thailand occurring with lignite which is mined in northern Thailand, particularly Mae Moh mine, Lampang Province, and might be a major source of 'leonardite' humate ore. The amount of lignite coal in this reserve area is about 1,139 million tons which represents highest volumes of both lignite and leonardite in Thailand. There are other sources of leonardite in the new mining areas such those in Lamphun, Phayao and Krabi Provinces. Quality and property of leonardite might vary widely from deposit to deposit. For appropriate use and application of leonardite, evaluation of its chemical properties is of importantce. Therefore, this study aims to investigate the chemical properties of leonardite and evaluation of its potential use in agriculture i.e. soil and crop yield improvement.

## Materials and Methods

### 1. Location Selection and Leonardite Sampling

Three locations regarded as different sources of leonardite: Mae Moh, Chiang Muan and Lee located in Lamphun, Lampang and Phayao Province, respectively, were surveyed and selected for this experiment. Three spots of each location were chosen for leonardite sampling except for Lee area where only two spots could be sampled. In each spot, 3 samples were collected for further analysis.

2. Chemical Analysis of Leonardite Samples

All leonardite samples were analyzed for nutrient contents; nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and manganese (Mn) (DOA, 2005). Some selected samples of leonardite were also analyzed for other characteristics; organic matter content (%OM), C/N ratio, and humic acid (%HA) (Nunan et al., 1998; Deborah and Burba, 1999; DOA, 2005).

## Results and Discussion

### Leonardite Sampling Areas

Leonardite properties might vary from place to place therefore we collected the samples from three different spots in Mae Moh and Chiang Muan mine. However in Lee mine, we could obtain the sample only from two spots since the mine was closed during our sampling. The Mae Moh basin located in Lampang Province is the largest lignite mine in Thailand with the reserves of 1.46 million tons. Several million tons of leonardite occur near-surface deposits and mix with lignite. We also suggested that this area is the largest reserve of leonardite because an expansion of the commercial use of leonardite was started in this area. However, other new mining areas such as those in Chiang Muan (Phayao Province) and Lee (Lamphun Province) were found to be good sources of leonardite. Physical appearance of leonardite in Mae Moh and Lee areas was dark brown or black. However, at Chinag Muan area we obtain only the sample in the collected piles near the mine's office, not that in the pit mine. In each spot, we randomly collected three samples of leonardite: therefore, a total of 24 leonardite samples were obtained for further investigation (Table1).

Table1 Location, spot and sample code of leonardite sampling.

| sampling location | sampling spot | sample code (number of samples) |
|---|---|---|
| 1) Mae Moh, Lampang | 1. Mae Moh 1 | LD1 (3) (Randomly collected 3 samples: LD1-1 to LD1- |
| | 2. Mae Moh 2 | LD2 (3) (Randomly collected 3 samples: LD2-1 to LD2- |
| | 3. Mae Moh 3 | LD3 (3) (Randomly collected 3 samples: LD3-1 to LD3- |
| 2) Chiang Muan, Phayao | 4. Chiang Muan 1 | LD4 (3) (Randomly collected 3 samples: LD4-1 to LD4- |
| | 5. Chiang Muan 2 | LD5 (3) (Randomly collected 3 samples: LD5-1 to LD5- |
| | 6. Chiang Muan 3 | LD6 (3) (Randomly collected 3 samples: LD6-1 to LD6- |
| 3) Lee , Lamphun | 7. Lee1 | LD7 (3) (Randomly collected 3 samples: LD7-1 to LD7- |
| | 8. Lee2 | LD8 (3) (Randomly collected 3 samples: LD8-1 to LD8- |

Chemical analysis of Leonardite Acidity and alkalinity of leonardite

The pH (acidity-alkalinity) values of leonardite samples ranged from 1.84-6.20 (Table 2). The leonardite samples from Mae Moh and Lee (LD1, LD2, LD3, LD7 and LD8) were considered as extremely acid with the pH values below 3 (pH 1.84-2.55). Pochadom et al. (2013) found that the pH of leonardite from lignite mine was around 4, which is strongly acidic. In our study; however, the pH values of the three samples from Chiang Muan; LD4, LD5 and LD6 were only moderately or slightly acid (5.61 to 6.20). This might due to the fact that leonardite was already contaminated with ground soil in the collected area. (Table 2). Recently, the pH of most agricultural soil in Thailand is rather acidic due to excess input of agrochemicals (Shutsrirung, 2008b). The beneficial effects of leonardite applied to those soils or to acid sulphate soils might not be expected if the pH of leonardite is not improved before application. In comtrast, in alkali soils, leonardite might improve the fertility of the soils and help to lower the pH of alkali soil to a level suitable to plant growth.

### The nutrients content in Leonardite

Although the pH values of leonardite was strongly acid, various nutrients necessary for plant growth were found to be in large quantities particularly trace elements (Table 2). Therefore, leonardite could still be used to improved nutrient level in soils. In our study, major elements including total nitrogen (% N) and total potassium (%$K_2O$) ranged from 0.25 to 0.60 %, and 1.02 to 2.71 %, respectively. From the results of other studies, total N varied widely from 0.73 to 1.79 % (Arif et al., 2013; Halil et al. 2011; Ali et al., 2007; Alfredo et al., 2005 and John et al., 1998), and our results were somewhat in between these values. On average, high value of K was found in the samples collected from Lee mine (1.90 – 2.71% $K_2O$). Alfredo et al., (2005) and Halil et al. 2011 reported the analyzed concentration of K in leonardite to be 0.51 and 3.97 (%K), respectively. The major nutrients (N and K) contained in leonardite were in the range of higher than the standard values of organic fertilizer (DOA, 2005). However, the total P values of all our leonardite samples were very low (65 – 480 mg $kg^{-1}$ = 0.0065-0.0480%) and much lower than the organic fertilizer standard values (>0.5%). The results were in accordance with all the previous reports of P concentration in leonardite (Arif et al., 2013; Halil et al. 2011; Ali et al., 2007; Alfredo et al., 2005 and John et al.,1998). Percentage of Ca and Mg of our samples ranged from 0.55 -3.36 % and 0.30-0.78%, respectively. On average Ca and Mg contents in compost range from 1.2-4.5% and 0.3-0.57%, respectively, depending on type of raw material use for composting (Shutsrirung, 2008). The analyzed values of trace elements were as follows; Fe, 1.62-5.33 %, Zn 19 - 149 mg $kg^{-1}$ and Mn 50 – 202 mg $kg^{-1}$, which are consistent with those by Arif et al. (2013), Halil et al. (2011), Ali et al. (2007), Alfredo et al. (2005) and John et al. (1998). Our results suggested that the P content of leonardite should be raised by applying high P materials such as rock phosphate before being developed as soil amendment and/or organic fertilizer. In addition, the pH values of the soil mixed with leonardite should be measured prior to crop cultivation since the Fe content in leonardite was quite high and might be toxic to the plant at low pH due to high solubility of all trace elements.

Table2 Total concentrations of selected plant nutrients contained in leonardite.

| Leonardite sample | pH | Total N (%) | Total $P_2O_5$ (mg $kg^{-1}$) | Total $K_2O$ (%) | Ca (%) | Mg (%) | Fe (%) | Zn (mg $kg^{-1}$) | Mn (mg $kg^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| LD1-1 | 2.51 | 0.48 | 340 | 1.61 | 1.88 | 0.57 | 3.25 | 75 | 110 |
| LD1-2 | 2.54 | 0.55 | 380 | 1.68 | 2.00 | 0.55 | 3.11 | 77 | 109 |
| LD1-3 | 2.48 | 0.60 | 340 | 1.68 | 2.22 | 0.54 | 3.22 | 54 | 102 |
| LD2-1 | 2.38 | 0.51 | 330 | 1.50 | 3.03 | 0.39 | 5.33 | 58 | 86 |
| LD2-2 | 2.38 | 0.51 | 380 | 1.40 | 3.05 | 0.43 | 5.24 | 56 | 86 |
| LD2-3 | 2.38 | 0.49 | 370 | 1.43 | 3.36 | 0.42 | 5.10 | 67 | 85 |
| LD3-1 | 2.49 | 0.54 | 460 | 1.44 | 1.98 | 0.50 | 3.21 | 69 | 112 |
| LD3-2 | 2.44 | 0.55 | 480 | 1.58 | 1.81 | 0.52 | 3.24 | 61 | 123 |
| LD3-3 | 2.55 | 0.57 | 480 | 1.51 | 2.10 | 0.51 | 3.35 | 63 | 126 |
| LD4-1 | 5.61 | 0.34 | 95 | 1.09 | 0.71 | 0.70 | 1.73 | 80 | 50 |
| LD4-2 | 5.63 | 0.36 | 71 | 1.02 | 0.71 | 0.70 | 1.63 | 63 | 60 |
| LD4-3 | 5.86 | 0.31 | 65 | 1.12 | 0.64 | 0.72 | 1.69 | 67 | 52 |
| LD5-1 | 6.18 | 0.33 | 87 | 1.13 | 0.66 | 0.72 | 1.78 | 63 | 57 |
| LD5-2 | 6.18 | 0.27 | 85 | 1.20 | 0.56 | 0.74 | 1.83 | 81 | 62 |
| LD5-3 | 6.11 | 0.28 | 88 | 1.14 | 0.57 | 0.73 | 1.79 | 80 | 55 |
| LD6-1 | 6.15 | 0.25 | 73 | 1.22 | 0.55 | 0.74 | 1.70 | 49 | 52 |
| LD6-2 | 6.11 | 0.28 | 66 | 1.16 | 0.55 | 0.73 | 1.62 | 64 | 56 |
| LD6-3 | 6.20 | 0.26 | 69 | 1.20 | 0.56 | 0.72 | 1.64 | 78 | 58 |
| LD7-1 | 2.40 | 0.45 | 392.7 | 2.61 | 0.72 | 0.63 | 2.18 | 139 | 197 |
| LD7-2 | 2.55 | 0.42 | 339.9 | 2.71 | 0.70 | 0.78 | 2.02 | 147 | 202 |
| LD7-3 | 2.52 | 0.43 | 309.3 | 2.57 | 1.92 | 0.40 | 1.89 | 149 | 212 |
| LD8-1 | 1.99 | 0.45 | 221.8 | 1.94 | 1.82 | 0.39 | 1.75 | 30 | 83 |
| LD8-2 | 1.96 | 0.48 | 151.9 | 2.19 | 1.54 | 0.47 | 2.67 | 25 | 86 |
| LD8-3 | 1.84 | 0.57 | 280.9 | 1.90 | 1.73 | 0.30 | 2.31 | 19 | 88 |
| Mean | 3.58 | 0.41 | 238.22 | 1.52 | 1.41 | 0.56 | 2.53 | 68.56 | 92.36 |
| ±SD | 1.82 | 0.1 | 152.46 | 0.51 | 0.9 | 0.14 | 1.18 | 33.02 | 47.95 |

**Organic properties and cation exchange capacity of leonardite**

We also analyzed some organic properties of leonardite i.e. percentages of organic matter (%OM), total carbon (%TC), total suphur (%TS) and humic acid (%HA). The ratio of carbon-to-nitrogen (C/N ratio) was also calculated. The quantity of organic matter ranged from 14.48 to 61.02 % (Table 3). As we discussed above that leonardite from Chiang Muan might be contaminated with soils in the sampling piles resulted in high pH values, the organic matter of leonardite from Chiang Maun, therefore, was quite low and was the lowest among all the samples (15.4-25.1%). All leonardite samples from Lee mine contained the highest amount of organic matter (48.66-61.02%). These amount of OM determined was in accordance with the OM values in leonardite determined by Ali et al. (2007) and Sanli et al. (2013) (43.60 and 54.5%, respectively). On average, the same trend was observed in the calculated values of TC and C/N ratio with value ranging from 8.61 to 34.30% and 25.40 to 69.66, respectively. The total sulfur ranged from 0.11 to 6.36% (Table 3). On average, the sulfur content in leonardite was negatively correlated with the pH value i.e. the lower the pH value, the higher TS content in leonardite. The pH values of leonardite from Mae Moh and Lee mines (LD1, LD2, LD3, LD7 and LD8) were lower than 3 (1.84-2.55) with the TS ranging from 4.22-6.36% while the pH values of leonardite from Chiang Muan (LD7 and LD8) were higher than 5.5 with the TS range from 0.41-0.73%. Leonardite with high sulfur content has a high potential to produce more acidity by sulfur oxidation when incorporating into the soils. Soil acidity can reduce crop yield by directly affecting roots and increasing the availability of toxic elements. Most plants perform best at a soil with pH between >5.5 to 6.8 (Shutsrirung, 2008b). Adjusting the pH of leonardite by lime or other materials which can raise its pH to the suitable range for crop production should be considered before soil application. Among organic matters, leonardite contains very high humic and fulvic acids (40-85%) compared to that of peat (10-20%) and compost (2-5%). Our results showed that leonardite from Mae Moh (LD1, LD2 and LD3) and Lee mine (LD7 and LD8) contained quite high amount of humic acid

(34.73-61.58 and 39.19-85.05%, respectively). Humus (humic acid and fulvic acid) in organic material acts as a significant reserve of plant nutrients and improves soil structure and water holding capacity. However, organic matter content in most agricultural soil under modern agriculture is quite low (<1%) thus very low humus content (Shutsrirung, 2008a). Organic matter depletion results in a decrease in crop productivity. Therefore, natural high humic acid material like leonardite could be used to improve organic matter, humic acid and some plant nutrient levels in the soils.

Table3 Selected chemical properties in leonardite

| Leonardite sample | OM (%) | TC (%) | TS (%) | C/N ratio | Humic acid (%) |
|---|---|---|---|---|---|
| LD1-1 | 30.76 | 11.87 | 5.18 | 37.17 | 58.55 |
| LD1-2 | 30.45 | 11.45 | 5.25 | 32.02 | 59.53 |
| LD1-3 | 31.27 | 11.50 | 5.14 | 30.48 | 55.8 |
| LD2-1 | 22.30 | 9.44 | 6.36 | 25.40 | 36.65 |
| LD2-2 | 22.87 | 9.16 | 5.50 | 26.08 | 34.73 |
| LD2-3 | 22.45 | 8.88 | 5.11 | 26.13 | 44.32 |
| LD3-1 | 28.00 | 12.70 | 4.22 | 29.93 | 56.15 |
| LD3-2 | 27.84 | 12.90 | 4.61 | 29.17 | 61.58 |
| LD3-3 | 29.83 | 13.03 | 4.75 | 30.22 | 57.25 |
| LD4-1 | 24.00 | 13.33 | 0.66 | 41.41 | 33.18 |
| LD4-2 | 25.16 | 13.23 | 0.73 | 40.71 | 31.97 |
| LD4-3 | 21.11 | 12.20 | 0.62 | 39.36 | 29.32 |
| LD5-1 | 21.03 | 12.37 | 0.40 | 37.43 | 31.63 |
| LD5-2 | 15.41 | 8.61 | 0.50 | 33.69 | 23.03 |
| LD5-3 | 17.29 | 9.63 | 0.41 | 35.61 | 24.86 |
| LD6-1 | 16.08 | 8.81 | 0.47 | 36.98 | 22.72 |
| LD6-2 | 18.18 | 9.96 | 0.46 | 37.72 | 25.82 |
| LD6-3 | 14.48 | 8.93 | 0.68 | 32.36 | 24.11 |
| LD7-1 | 53.78 | 30.4 | 4.96 | 69.49 | 44.22 |
| LD7-2 | 48.66 | 24.7 | 4.87 | 66.64 | 41.85 |
| LD7-3 | 48.78 | 25.9 | 5.33 | 66.09 | 39.19 |
| LD8-1 | 53.96 | 34.3 | 5.12 | 69.66 | 72.44 |
| LD8-2 | 54.75 | 28.8 | 5.27 | 66.94 | 77.86 |
| LD8-3 | 61.02 | 29.6 | 5.01 | 62.32 | 85.05 |
| Mean | 29.58 | 14.87 | 2.85 | 40.12 | 42.87 |
| ±SD | 14.42 | 8.26 | 2.35 | 15.56 | 18.31 |

## Conclusion

The properties of leonardite varied from place to place. The pH value of most leonardite samples was extremely acid (pH <3) except for that from Chiang Muan. Leonardite from Mae Moh and Lee mine contained quite high major plant nutrients (except for P), high trace elements, and very high humic acid content. Most samples indicated high potential of leonardite to improve soil fertility and crop yield; however, some properties such as pH value and P content should be improved before application.

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