

UDC 552.52:631.823:631.415  
AGRIS P33

https://doi.org/10.33619/2414-2948/65/29

**THE COMPARISON STUDY OF SOIL PERMEABILITY CHARACTERISTIC  
FROM CLAY - MATERIAL MIXING CRAYS GILVUS  
(*Macrotermes gilvus* Hagen) AND BENTONITE AS SOIL LINER**

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**СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ ПРОНИЦАЕМОСТИ ГРУНТОВЫХ  
ПРОСЛОЕК ИЗ СМЕСИ ГЛИНЫ И МАТЕРИАЛА ТЕРМИТНИКОВ  
*Macrotermes gilvus* Hagen И БЕНТОНИТА**

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*Abstract.* Liner has a role as sealing or waterproof layer that was made to prevent water to be absorbed by the soil. A good liner is made within the minimum hydraulic conductivity (k) within the requirements of 1.0E-07 cm/s. This study was conducted to determine the extent on the difference between hydraulic conductivity (k) bentonite and termite nest (*Macrotermes gilvus* Hagen) as one of the materials that have the potential to obtain small value of hydraulic conductivity (k). This research was conducted by examining the effect of hydraulic conductivity (k) value on the percentage of additives, such as bentonite and termite nest material (*M. gilvus* Hagen), and then compared the hydraulic conductivity (k) values of those two materials. The variations in the additive content percentage are 5%, 15%, and 30% with laterite as a base material. Based on the results of falling head test at minimum density of 95%  $\gamma_{dmax}$ , the smallest hydraulic conductivity (k) value was obtained by bentonite with 30% mixed percentage level of 6.9390E-08 cm/s and the smallest hydraulic conductivity (k) value of termite nests was 1.2646E-07 cm/s with the content percentage of 5% mixture.

*Аннотация.* Прослойка выполняет роль герметизирующего или водонепроницаемого слоя, который предотвращает впитывание воды грунтом. Хороший гидроизолирующий материал изготавливается с минимальной гидравлической проводимостью (k) в пределах требований 1,0E-07 см/с. Это исследование было проведено для определения степени разницы между гидравлической проводимостью (k) бентонита и материала термитника (*Macrotermes gilvus* Hagen) как одного из материалов, способных обеспечить низкое значение гидравлической проводимости (k). Это исследование проводилось путем изучения влияния значения гидравлической проводимости (k) на процентное содержание добавок, таких как бентонит и материал термитников (*M. gilvus* Hagen), а затем сравнивались значения гидравлической проводимости (k) этих двух материалов. Различия в процентном содержании добавки составляют 5%, 15% и 30% с латеритом в качестве основного материала. На основании результатов испытания падающим поршнем при минимальной плотности 95%  $\gamma_{dmax}$  наименьшее значение гидравлической проводимости (k) было получено для бентонита

с 30% смешанным процентным уровнем  $6,9390E-08$  см/с и наименьшей гидравлической проводимостью ( $k$ ). Величина гидравлической проводимости материала термитников составила  $1,2646E-07$  см/с при процентном содержании смеси 5%.

*Keywords:* liner, bentonite, termite nests, hydraulic conductivity.

*Ключевые слова:* прослойка, бентонит, термитники, гидравлическая проводимость.

### *Introduction*

To obtain a small hydraulic conductivity ( $k$ ), besides compaction, the selection of soil type also affects the behaviour of hydraulic conductivity ( $k$ ). The selection of the clay type will affect the behaviour of the obtained clay [1].

Nowadays, the material liner that commonly used is bentonite. Bentonite is a type of 2:1 clay that contains more than 85% of montmorillonite minerals [2]. The characteristic and shrinkage of montmorillonite give bentonite the low soil permeability.

The expansion capacity depends on the level of sodium-montmorillonite. Low swelling bentonite has significant quantity of calcium-montmorillonite due to the limitation of the water absorption layer will not expand as far as sodium-montmorillonite. Low swelling bentonite has the significant quantity of calcium-montmorillonite which is due to the limitation of water absorption layer will not expand the sodium-montmorillonite [3].

The dispersed subterranean termites depend on the type of soil to determine its distribution [4]. In particular, Subterranean termites tend to take up the soil types that consist of majority of loam or clay soils, therefore sandy soil is not really used by subterranean termites because this type of soil does not have the large amount of organic content to meet the requirements of this termite type [5].

In the process of making termite hills, termites modify the physical, chemical, and biochemical characteristics not only from the soil to create nests, but also to its organic compounds [6]. Besides, the structure of subterranean termite nest will be stronger if the material used by the termites consists of clay [7].

In this research, the testing on the effect of hydraulic conductivity ( $k$ ) was done toward the addition of termite nest material by comparing the effect of bentonite, thus the difference of the produced effect by termite nest material can be seen clearly.

### *Literature Review*

Clay used as a liner should be made through special treatment, therefore it has a value of hydraulic conductivity ( $k$ ) that can reach a smaller number or equal to  $1,0E-07$  cm/s. The aspect that needs to be considered in order to conduct the hydraulic conductivity ( $k$ ) at a low number is focused on the percentage of mixed soil.

The percentage of clay composition from mixed soil that used for liners will not be effective if the clay percentage is higher than 20%. The higher increase in plasticity of the clay, thus the hydraulic conductivity ( $k$ ) in liner manufacture process, will affect the decrease of hydraulic conductivity ( $k$ ) value.

Considerations for carrying out work in field of using low plasticity soils are more widely used than high-plasticity soils, because low plasticity soils is easier to be mixed and compacted. Soils with low plasticity have a less chance of desiccation [8].

Hydraulic conductivity ( $k$ ) or seepage coefficient depends on several factors, such as viscosity, pore-size distribution, grading, pore number, angularity, and soil saturation. Within the

soil of clay, the soil structure has an important influence in determining hydraulic conductivity ( $k$ ). Another aspect that affects the properties of hydraulic conductivity ( $k$ ) is the nature of ion that occurs and become thick in the water layer among the grains [9].

Montmorillonite is a type of 2:1 soil with dioctahedral gibbsite sheets placed between two tetrahedral silica sheets. The chemical bonds among the unit cells of montmorillonite are weak, water and polar fluid can easily enter between the bonds of the unit cells. As a result, the montmorillonite particles are quite small and can be dispersed onto the sheet of the unit cell thickness ( $10 \text{ \AA}$ ) in water [10].

Table 1.

GENERAL PRICE OF HYDRAULIC CONDUCTIVITY ( $k$ ) [5]

Soil Type	Hydraulic Conductivity ( $k$ )	
	cm/s	ft/m
Clean gravel	1.0–100	2.0–200
Rough sand	1.0–0.01	2.0–0.02
Sand	0.01–0.001	0.02–0.002
Silt	0.001–1.0E-05	0.002–2.0E-05
Clay	< 1.0E-06	< 2.0E-06

Natural forests in tropical geographic areas within the availability of large amounts of organic are suitable habitats of subterranean termites on genus *Macrotermes*. The soil type in the forest of tropical area makes termite loves to stay in this habitat [11]. This soil used by this termite to obtain nutrients and construction that supports the life of subterranean termites [12].

The interesting aspect of the structure and framework of genus *Macrotermes* termite nest is that the type of termite can replicate the climate condition of the soil and stable during any changes, which is  $30^\circ\text{C}$  with  $\text{CO}_2$  levels of 1.5 ppm [10]. The rough walls of termite nest building constructed from a little soil which cemented with termite saliva and naturally dried by the sun [5].

Dense liners happen due to their low permeability (hydraulic conductivity), restricting the seepage instady-state of facility. On the facility of waste management, liner was designed to delay the redemption of leachate during the transit time and obtain the proper structure stability to support the components and others. Liner not only used in waste management facilities, but also in many other applications such as water storage and transportation structures [13].

Liners usually construct from native soil contains a large amount of clay particles. In some cases of other materials that did not contain enough clay, the material will be mixed with other materials such as bentonite. The liner can be overwritten with one or more flexible membrane liners and leachate drainage system. Basically, the use of liners is to provide a barrier between leachate/waste and soil water by restricting any seepage to be absorbed inside the soil [12, 14].

#### Research Methodology

The soil sample of this research is disturbed soil with laterite soil as the basic material. The additives used materials from termite nests and bentonite that mixed in laterite soil, within the percentage of each 5%, 15%, and 30%.

As the basic of the research about hydraulic conductivity ( $k$ ), it is necessary to test the physical and mechanical properties of the material. These tests include specific gravity ( $G_s$ ) (ASTM D854-92), Atterberg limit (ASTM D4318-93), standard test method for grain size of soils (ASTM D422-63), standard compacting test (ASTM D698), and direct shear test (ASTM D3080).

Infalling head test (ASTM D18.04.85.03) the test was carried out within 3 samples at each level of mixture by variation levels of 5%, 15%, and 30% in material of termite nest and bentonite.

The sample was tested with an approximate sample (L) of 2 cm bypermeameter as shown in Figure 1. To measure the falling head testing process for water level changes in burette, it used a scale/ruler.

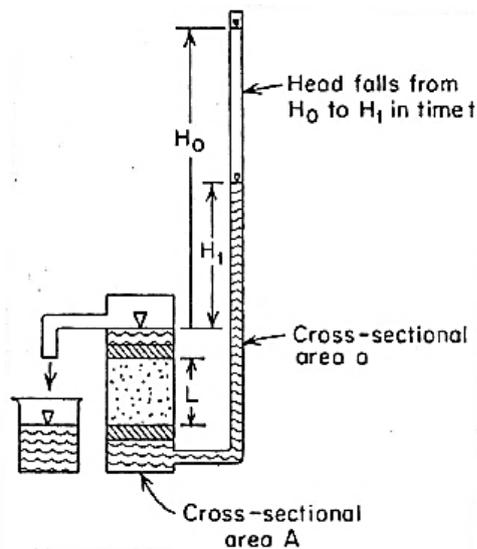


Figure 1. Permeameter

The test object that has been tested will enter the completion stage to get the hydraulic conductivity within the equation of:

$$k = 2,303 \frac{a \cdot L}{A \cdot t} \log \frac{h_1}{h_2} \quad (1)$$

Which means: a = burette total area(cm<sup>2</sup>), A = sample total area (cm<sup>2</sup>), L = Sample length (cm), t = time (detik), h<sub>1</sub> = first heighthhead (cm), h<sub>2</sub> = lastheighthhead (cm).

### Result and Discussion

The results of physical properties testing samples of laterite, termite nests, and bentonite before mixing can be seen in Table 2. The test showed that not much different in results which each test values has quite close relation, while the bentonite sample obtain different results from LL of 351.71%, PI of 307.03% with clay grain size of 90.28%.

It can be determined from the results of physical properties test on laterite samples and termite nests classified as low plasticity clay (CL) and bentonite as high plasticity clay (CH).

Table 2.

#### AVERAGE VALUE OF PHYSICAL PROPERTIES PARAMETERS AND INDEX PROPERTIES

Parameter	Laterite	Termite Nests	Bentonite
Gs	2.68	2.66	2.72
LL	43.56%	40.23%	351.71%
PL	26.98%	24.87%	44.68%
PI	16.58%	15.36%	307.03%
Gravel	1.09%	0.30%	0.00%
Coarse sand	2.32%	4.85%	0.00%
Medium sand	2.14%	3.76%	0.00%
Fine sand	4.95%	7.59%	1.39%
Silt	39.09%	30.37%	8.33%
Clay	50.41%	53.14%	90.28%

*The Relationship of Termite Nests and Bentonite addition to Dry Density*

The addition of 30% termite nests has considerable effect on dry density, where the value of dry density termite nests at the range 30% obtained a dry density of 1.66 g/cm<sup>3</sup> decreased at range 15% of 1.27 g/cm<sup>3</sup> and range 5% obtained a value of 1.42 g/cm<sup>3</sup>. Compared to bentonite with additional range of 5%, 15%, and 30%, the obtained values were close to each other, which obtain 1.32 g/cm<sup>3</sup> at the range of 5% and increase to 1.35 g/cm<sup>3</sup> at the range of 15% and decrease to 1,32 g/cm<sup>3</sup> at the range of 30%.

It is known that each range addition of termite nests have sufficient effect it can be shown by the changes in density that quite far compared to the mixture of bentonite. The relationship figure of adding laterite bentonite and laterite termite nest toward the dry density can be seen in Figure 1 below.

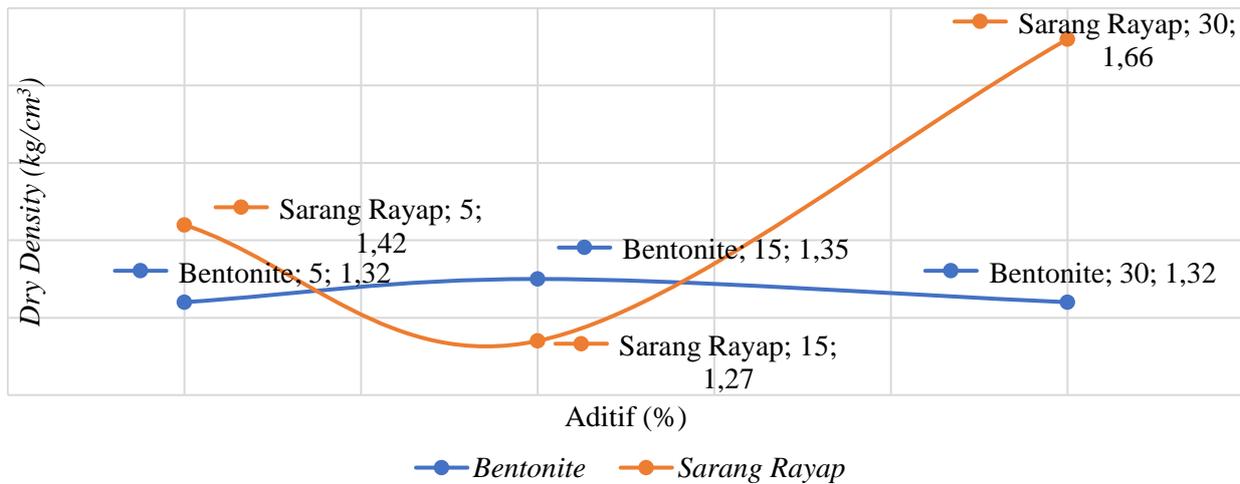


Figure 2. The Relationship of Increasing Percentage of Laterite-Bentonite Mixed Content with Laterite-Termite Nests on Dry Density

*The Relationship of Termite Nests and Bentonite addition to Cohesion and Inner Shear Angle*

In direct shear testing for the sample testing of termite nests and bentonite, the greatest cohesion value was obtained in termite nests at the range of 15% by the total 0.1821 kg/cm<sup>2</sup> and bentonite of 0.1206 kg/cm<sup>2</sup> at the percentage of 30%. For cohesion, the largest angle was obtained in termite nests of 19.57 under the range of 15%, and in bentonite, it obtains 22.95° at the range of 30%.

The effect of the termite nests addition provides higher cohesion than bentonite, however, the addition of bentonite has an effect on the inner shear angle. If cohesion related to density or dry density, it is related to the termite nests that also have a considerable influence on their density.

Table 3.

TEST RESULTS FROM THE DIRECT SHEAR TEST			
Material	Range	C (kg/cm <sup>2</sup> )	φ (°)
Bentonite	5%	0.1044	17.74
	15%	0.1157	20.47
	30%	0.1206	22.95
Termite nests	5%	0.1433	18.23
	15%	0.1821	19.57
	30%	0.1425	18.93

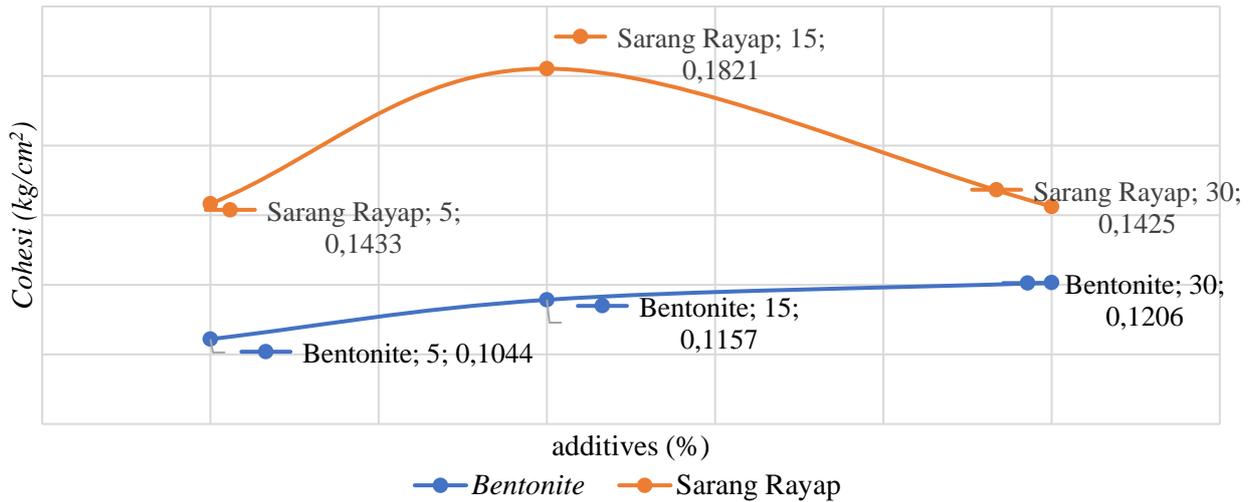


Figure 3. The Relationship of Increasing the range of Bentonite and Termite Nests levels on Cohesion

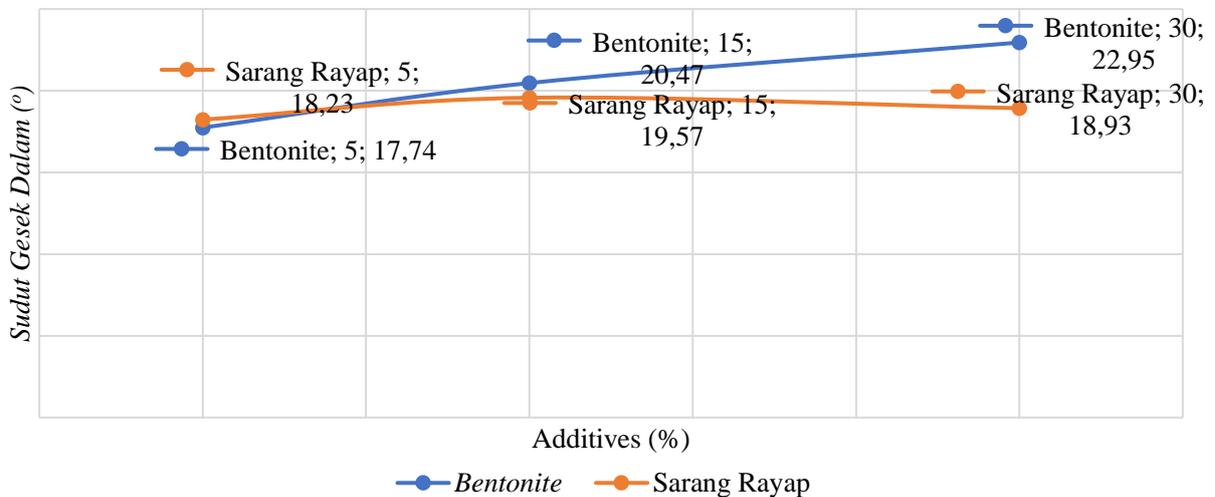


Figure 4. The relationship of bentonite and termite nests addition range to the inner sliding angle

*The Relationship of Termite Nest and Bentonite Addition toward Hydraulic Conductivity*

In the falling head test, it can be seen that bentonite has a big influence on hydraulic conductivity. It can be seen in the percentage of bentonite range of 30%, the value of hydraulic conductivity from bentonite was able to reach  $6.9390E-08$  cm/s. In the range of 30%, bentonite has reached the requirements as a liner within the minimum of  $1.0E-07$  cm/s, however, at the range of 5% and 15%, bentonite has not been able yet to reach the minimum requirements as liner.

In this study, bentonite has a role in comparison with the hydraulic conductivity of termite nests. For the termite nests testing in the falling head, the obtained value was not better than bentonite, which the smallest value obtained  $1.2646E-07$  cm/s within the percentage of 5%. Meanwhile, within the increase in the percentage of termite nests at 15% and 30%, the value of hydraulic conductivity increases to  $3.0E-07$  cm/s  $3.1590E-07$  cm/s at the range of 15% and  $3.0668$  cm/s the range of 30%

The obtained testing result can be seen as written in Figure 4 below.

*The Addition of Termite Nest toward the improvement of Laterite soils Hydraulic Conductivity*

If the termite nest still not as good as bentonite at hydraulic conductivity value, will the addition of termite nests can reduce the hydraulic conductivity of the laterite soil?

Plain or pure laterite soil test using the falling head test for 3 and 7 days that was obtained with an approximate average of  $1.20E-06$  cm/s. It proves that the laterite soil can be stabilized for hydraulic conductivity by using termite nests.

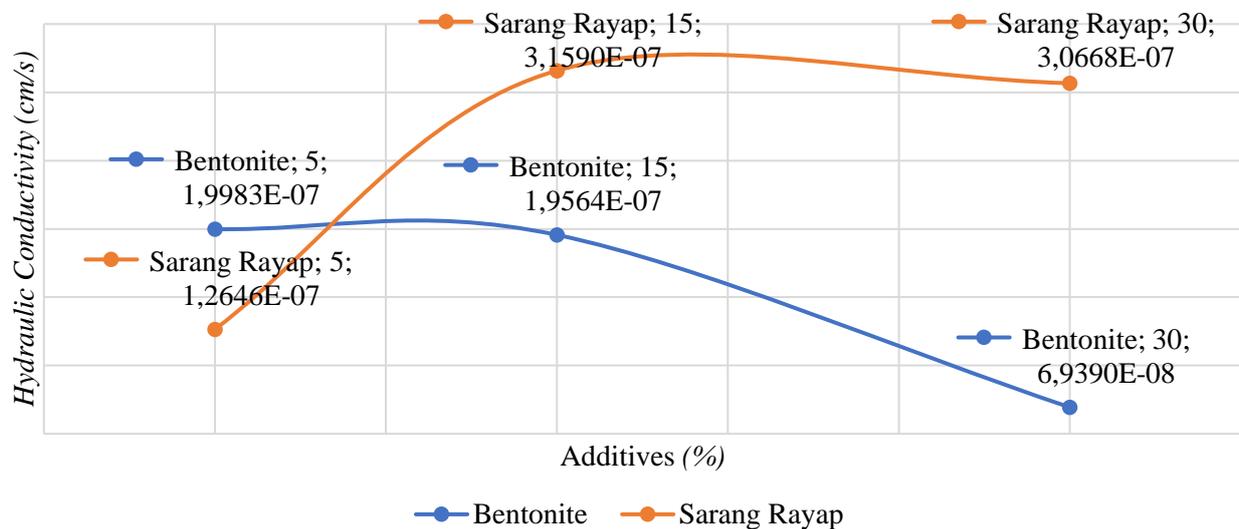


Figure 5. The Relationship of the Percentage of Addition of Bentonite and Termite Nests on Hydraulic Conductivity (k)

*Conclusion*

The effect of the termite nests addition on laterite soils can provide a better value of hydraulic conductivity in laterite soils, however it will not as good as the value of hydraulic conductivity of bentonite. The difference is quite far, which the addition of termite nests, the hydraulic conductivity value has not reached the minimum requirement at  $1.0E-07$  cm/s, whereas by adding bentonite, the content percentages is 30%, the obtained hydraulic conductivity value is  $6.9390E-08$  cm/s.

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Работа поступила  
в редакцию 29.03.2021 г.

Принята к публикации  
04.03.2021 г.

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Ссылка для цитирования:

Ahmad Ridhani Noorfauzi, Rusdiansyah The Comparison Study of Soil Permeability Characteristic From Clay - Material Mixing Crays Gilvus (*Macrotermes gilvus* Hagen) and Bentonite as Soil Liner // Бюллетень науки и практики. 2021. Т. 7. №4. С. 258-266. <https://doi.org/10.33619/2414-2948/65/29>

Cite as (APA):

Ahmad Ridhani Noorfauzi, & Rusdiansyah (2021). The Comparison Study of Soil Permeability Characteristic From Clay - Material Mixing Crays Gilvus (*Macrotermes gilvus* Hagen) and Bentonite as Soil Liner. *Bulletin of Science and Practice*, 7(4), 258-266. <https://doi.org/10.33619/2414-2948/65/29>