UDC 631.86:633/635
DOI https://doi.org/10.32848/0135-2369.2023.79.11

EFFECT OF BIOGAS SLURRY RETURNING TO FIELD ON SOIL PHOSPHATASE ACTIVITY

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Problem statement. The biogas slurry formed after anaerobic fermentation of animal feces contains a large amount of nutrients such as nitrogen, phosphorus and potassium, as well as a variety of trace elements such as iron, zinc and manganese. Therefore, returning biogas slurry to the field is conducive to improving soil fertility improving soil environment [1] and crop yields [2]. Soil enzymes are biocatalysts in the process of organic matter cycling in the soil and can participate in the decomposition of organic matter, nutrient cycling, residual degradation and other processes in the soil [3–4]. Application of mineral and organic fertilizers, biochar, ameliorants, plowing of plant residues, irrigation and other factors affect the biological activity of the soil, changes the content of nutrient fractions [5; 6].

Toxic polluting elements, a change in the pH of the soil environment leads to a change in phosphatase activity [7; 8].

Applying manure increases the activity of acid and alkaline phosphatase, but at high rates, an increase in the activity of nitrogenous biota and acid phosphatase can be observed. Liming stimulates the growth of alkaline phosphatase activity and suppression of acid [9; 10].

Jager E.A. et al. (2023) obtained in their research, that "no connection between N fixation rates and phosphatase activity" [11]. Conducting organic farming compared to traditional farming shows an increase in microbiological activity, and in particular, alkaline phosphatase [12–14]. Digestate is a multicomponent fertilizer. Research on the effect of digestate on the enzymatic activity of the soil, in particular, phosphatase activity, is currently limited, and this is promising in the future for the optimization of phosphorus nutrition of plants [15].

Keane et al. (2020) noted that the activity of acid phosphatase doubles with the addition of nitrogen fertilizers compared to the addition of phosphorous [16]. Meta-analysis by Janes-Bassett et al. shows the lack of data on phosphatase activity on different backgrounds, with different application of organic and mineral fertilizers, by vegetative plants [17].

The purpose of this paper is a short review about the influence of fertilizers and plants on phosphatase activity in the soil, the reasons for the inhibition of alkaline and acid phosphatase.

Analysis of recent research and publications.

1. Effects of different concentration of biogas slurry on soil phosphatase activity

Soil enzyme is the direct reflection of soil biological activity. Research showed that biogas slurry can improve soil phosphatase activity [4; 5], which increased with the increase of biogas slurry dosage [18; 19]. Sun Fengxia studied the characteristics of rubber seedling growth and soil fertility under different amounts of biogas slurry [20]. The results showed that the acid phosphatase activity range was 0.66–1.33 mg/g, which was higher than that of the control group at the later stage of the experiment. This was mainly because the biogas slurry contained a large number of organic substances and trace elements that were not completely decomposed, they slowly released nutrients as they entered the soil. By November, soil acid phosphatase activity gradually increased with the increase of biogas slurry amount. Du Yaning's study on biogas slurry from plantation showed that biogas slurry had a significant effect on soil phosphatase activity($P<0.01$) [21]. In the 0–10 cm soil layer, the phosphatase activity increased with the increase of biogas slurry concentration, and the difference was significant. In the 10–25 cm soil layer, the phosphatase activity reached the maximum at the medium concentration of biogas slurry, and then decreased with the increase of fertilization concentration.

Danni feng's research showed that with the increase of biogas slurry, the phosphatase activity increased first and then decreased [22], which is consistent with Yanjun chai's research [23]. It may be because the pH value of biogas slurry is slightly alkaline, and it is a product of anaerobic fermentation with strong reducing capacity, and the increase of biogas slurry has an inhibitory effect on the acid phosphatase.

2. Effect of biogas slurry application on vertical spatial distribution of soil phosphatase activity

Du Yaning found that in 0–10 cm soil layer, the phosphatase activity in control group, low concentration and high concentration biogas slurry was significantly higher than that in 10–25 cm soil layer ($P<0.05$) [21]. Wang Guifang studied the effect of biogas slurry combined with potassium fertilizer on soil phosphatase activity in apple orchard [24]. The results showed that the soil phosphatase activity in surface layer (0–20 cm) and subsurface layer (20–40 cm) was higher than that in the third layer (40–60 cm), whether applying biogas slurry with different concentrations alone or applying biogas slurry with different concentrations combined with potassium fertilizer. The reason is that the phosphatase activity mainly comes from plant roots, and the roots of apple are mostly distributed at 0–40 cm. Therefore, the phosphatase activity of surface and subsurface soil is higher than that of 40–60cm soil layer [24].

The vertical distribution of soil phosphatase activity was related to tree age. Qin Xiaofei studied the effects of applying biogas slurry on soil characteristics of apple orchards of different tree ages [25]. In the soil with the same tree age and different depths, the phosphatase activity in the soil with 5 and 10 years of apple planting showed a decreasing trend with the increase of depth, and the difference was significant, while in the soil with 15 years of apple planting, the phosphatase activity in the soil with 40 cm and 60 cm depth was similar. However, the phosphatase activity is smaller than that at the depth of 20 cm. In the soil of 20 years of tree age, the phosphatase activity in the soil at the depth of 20 cm and 40 cm is similar, but the phosphatase activity in the soil at the depth of 60 cm is higher than that at the depth of 60 cm [25].

3. Effect of biogas slurry application on dynamic change of soil phosphatase activity

The biogas slurry contains abundant organic components, and the permanent release of fertilizer efficiency is closely related to the dynamic changes of soil enzyme activities. Du Yanning's research showed that biogas slurry changed the seasonal dynamic variation trend of soil phosphatase activity, and the highest soil phosphatase activity changed from June to September, and biogas slurry had a significant impact on the seasonal dynamic change of soil phosphatase activity [21]. Sun Fengxia's research also showed that biogas slurry had a certain effect on soil enzyme activities, which fluctuated with the months. From the time scale, the amount of biogas slurry irrigation has a great influence on soil acid phosphatase activity from March to July, which may be related to temperature change [20]. Qin Xiaofei studied phosphatase activity of soil in the same depth and different duration of biogas slurry, at the depth of 20 cm, the phosphatase activity in the soil was the highest in the two years after applying biogas slurry, which was 10.6 % higher than that without applying biogas slurry [25]. However, after applying biogas slurry for four years, the phosphatase activity in the soil had little change, while the phosphatase activity in the soil without applying biogas slurry was similar. At the depth of 40 cm, the phosphatase activity was roughly the same as that of the control regardless of whether biogas slurry was applied for 2 years or 4 years, while at the depth of 60 cm, the phosphatase activity was similar in the two years without biogas slurry fertilizer and in the two years after biogas slurry fertilizer was applied, which was greater than that in the four years after biogas slurry fertilizer was applied, but the difference was not significant [25]. Yang Lun studied the effect of different amount of biogas slurry applied for 5 months on the phosphatase activity in purple soil [26]. The results showed that the soil phosphatase activity was low in the first month, peaked in the third month, and then decreased in the last month. This is consistent with the research results of Zhang Wudi [4]. With the growth of vegetables, phosphatase activity gradually increases, and then continues to decrease after reaching the maximum value.

4. Effect of combined fertilization on soil phosphatase activity

As a high quality organic liquid fertilizer, biogas slurry contains a large number of available nutrients and various nutrients needed for plant growth. Combined application of biogas slurry and fertilizer can significantly promote the improvement of soil phosphatase activity, stimulate the mineralization and decomposition of combined phosphorus in the soil, and promote the release of more inorganic phosphorus elements in the soil. Du Yanning studied the effects of biogas slurry and biochar application on soil phosphatase activity of poplar plantation [21]. The results showed that in 0–10 cm soil layer, the effects of biogas slurry and biochar combined application on soil phosphatase activity were as follows: Only apply biogas slurry. In the 10–25 cm soil layer, there is no significant difference between the application of biogas slurry and biochar and the single application of biogas slurry [21]. Wang Guifang studied the effect of biogas slurry combined with potassium fertilizer on soil phosphatase activity in apple orchard [24]. The results showed that the control was the highest, followed by biogas slurry, and the combination of biogas slurry and potassium fertilizer was the lowest. And with the increase of potassium fertilizer concentration, there was a significant difference from the control. The combined application of biogas slurry and potassium fertilizer with the highest concentration in the surface layer (0–20 cm), subsurface layer (20–40 cm) and third layer (40–60 cm) decreased by 55.72 %, 50.25 % and 62.89 % compared with the control, respectively. This indicates that biogas slurry combined with potassium fertilizer has an inhibitory effect on the activity of alkaline phosphatase, and the alkaline phosphatase activity in each treatment is reduced to varying degrees compared with the control, indicating that no treatment can protect the microenvironment for the survival of soil enzymes to a certain extent [24]. The effect of biogas slurry on the soil of Changshanhuyou forest was studied, and the results showed that the soil phosphatase activity of the combined application of different amounts of biogas slurry, chemical fertilizer and organic fertilizer was close to that of soil phosphatase without fertilizer, reflecting that the soil phosphatase activity has a certain stability and has a strong buffering capacity to external disturbances [27].

5. Effects of different tree ages on phosphatase activity

Soil phosphatase activity is not only affected by soil physical and chemical properties, but also related to tree age. Qin Xiaofei studied the effects of applying biogas slurry on soil characteristics of apple orchards of different tree ages [25]. The results showed that at the depth of 20 cm, the phosphatase activity of 5 years old was the smallest, followed by that of 10 years old, and the activity of 15 years and 20 years old was the same. At the depth of 40 cm, the phosphatase activity increased with the increase of tree age, but the difference was not significant. At the depth of 60cm, the phosphatase activity reached the maximum value at 15 years and the minimum value at 5 years [25]. Trees of different ages require different amounts of phosphorus, in order to improve nutrient cycling, the phosphatase activity involved in phosphorus cycling in soil also changed correspondingly.

Conclusions. Biogas slurry is not only containing rich nutrients also contains rich bioactive substances, a moderate amount of fertilizer can effectively activate soil phosphatase activity, promote the change of the soil within the physiological and biochemical process, speed up the circulation rate of soil phosphorus, improved soil quality, has good application value, but the excessive dosage of biogas slurry can reduce the phosphatase activity, is also likely to lead to soil and groundwater pollution.

Biogas slurry nutrient content is rich, but its composition is relatively complex, the vertical distribution of phosphatase activity in soil is related to the amount of biogas slurry, the application period, the number of topdressing and the combined application of fertilizer. One fertilization method may not be suitable for all soils. In practice, it should be determined according to the comprehensive study of soil fertility, biogas slurry fertility, climate and other conditions.

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Zhang X., Zakharchenko E.A. Effect of biogas slurry returning to field on soil phosphatase activity

Returning biogas slurry to the field is an effective way to realize resource reuse between animal husbandry and planting industry, which has been widely concerned in recent years. The incorporation of biogas suspension into the soil affects the soil microbiome. Soil enzymes play an important role in the soil ecosystem. Phosphatase is a widely existed hydrolase in soil, which can catalyze the conversion reaction of organic phosphorus to inorganic phosphorus. It is very important to improve the availability of soil phosphorus. Therefore, the purpose of the article was to analyze the influence of fertilizers and plants on phosphatase activity in the soil, the reasons for the inhibition of alkaline and acid phosphatase.

It is an index to evaluate the direction and intensity of soil phosphorus biotransformation, and also an important index of soil fertility. Phosphatase activity is affected by soil fertility and surrounding environment. After applying biogas slurry, soil environmental conditions, nutrient status, microbial species and diversity change, and phosphatase activity changes accordingly.

The activity of phosphatase is strongly influenced by weather conditions, water consumption, and the level of consumption by plants during the growing season. Due to the increase in the price of mineral fertilizers, in particular, phosphorus fertilizers, biogas suspension/digestate will be a good solution for overcoming phosphorus deficiency in the crop cultivation.

In general, the topic of the reaction of microbiota, in particular phosphatase, to the application of biogas suspension at different application doses with or without mineral fertilizers, on soils with different texture and agricultural use, is insufficiently studied. There is practically no information from Ukrainian scientists about the effectiveness of biogas suspension of animal origin (pig manure) on the enzymatic activity of chernozem soils.

Key words: phosphorus, soil, digestate, waste management; sewage, enzymes, biological activity, organic fertilizer.

Чжан С., Захарченко Е.А. Вплив внесення біогазової суспензії в грунт на фосфатазну активність

Повернення біогазового шламу в поле є ефективним способом реалізації повторного використання ресурсів у тваринництві та рослинництві, що викликає широке занепокоєння в останні роки. Внесення біогазової суспензії в грунт впливає на грунтовий мікробіом. Ґрунтові ферменти відіграють важливу роль у ґрунтовій екосистемі. Фосфатаза – широко поширена в ґрунті гідролаза, яка може каталізувати реакцію перетворення органічного фосфору в неорганічний. Дуже важливо підвищити забезпеченість ґрунту фосфором. Тому метою статті було проаналізувати вплив добрив, рослин на фосфатазну активність в грунті, причини інгібування лужної та кислої фосфатази. Цей індикатор може використовуватися для оцінки спрямованості та інтенсивності біотрансформації фосфору в ґрунті, а також важливим показником родючості ґрунту. На активність фосфатази впливає родючість ґрунту та навколишнє середовище. Після застосування біогазової суспензії змінюються екологічні умови ґрунту, стан поживних речовин, види та різноманітність мікроорганізмів, а також відповідно змінюється активність фосфатази. Дуже впливають на діяльність фосфатази погодні умови, водоспоживання, рівень споживання рослинами протягом вегетаційного періоду. Через здорожчання мінеральних добрив, зокрема, фосфорних, біогазова суспензія/дигестат буде гарним рішенням для подолання дефіциту фосфору при вирощуванні с.-г. рослин. В цілому, недостатньо освітлена тема реакції мікробіоти, зокрема фосфатази, на внесення біогазової суспензії за різними дозами внесення з мінеральними добривами чи без них, на грунтах з різним механічним складом та сільськогосподарським використанням. Практично відсутні відомості українських вчених про ефективність біогазової суспензії тваринного походження (свинячого гною) на ферментативну активність чорноземних грунтів.

Ключові слова: фосфор, ґрунт, дигестат, поводження з відходами, стічні води, ферменти, біологічна активність, органічні добрива.