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Stabilization of Al-Rustamiya Waste Water Treatment Plant Sludge Using Lime

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ABSTRACT

A study was performed to evaluate heavy metals removal from sewage sludge using lime. The processes of stabilization using alkaline chemicals operating on a simple principle of raising pH to 12 or higher, with sufficient mixing and suitable contact time to ensure that immobilization can reduce heavy metals. A 0.157 m^3 tank was designed to treat Al-Rustemeyia wastewater treatment plant sludge. Characteristics of raw sludge were examined through two parameters: pH and heavy metal analysis. Different lime doses of (0- 25) g CaO/100 g sludge were mixed manually with raw sludge in a rotating drum. The samples were analyzed two hours after mixing. pH and heavy metals results were compared with EPA and National Iraqi Standard (NIS). Results showed as lime was added, the concentration of heavy metals decreases the higher the dose, the less heavy metals concentrations in the sludge. Although the concentration of heavy metals in the sludge was among the determinants according to the US Environmental Protection Agency, the results showed that 750 g of lime per 3 kg of sludge had reduced the concentration of heavy metals zinc from (662.934) mg/kg sludge to (452.998) mg/kg sludge, copper from (113.101) mg/kg sludge to (64.981) mg/kg sludge, lead from (91.215) mg/kg sludge to (53.307) mg/kg sludge, nickel from 107.257 mg/kg sludge to (50.478) mg/kg sludge, molybdenum from (13.743) mg/kg sludge to (8.724) mg/kg sludge). At the same time, the dose of 450 g lime per 3 kg of sludge had reduced the concentration of chromium from (110.577) mg/kg sludge to (0) mg/kg sludge.

Keywords: Wastewater Treatment Plants, Sewage Sludge, Biosolids, Heavy Metals, Quicklime

تثبيت حمأة محطة الرستمية لمعالجة مياه الصرف الصحي باستخدام الجير

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الخلاصة

تم إجراء دراسة لتقييم جدوى استعمال ماء الجير مع حمأة المجاري في ازالة المعادن الثقيلة ، تمت عمليات التثبيت باستخدام المواد الكيميائية القلوية التي تعمل على مبدأ بسيط لرفع الرقم الهيدروجيني إلى 12 أو أعلى ، مع خلط

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كفوء ووقت اتصال مناسب لضمان تثبيت وازالة وتقليل المعادن الثقيلة. تم تصميم خزان مساحته 0.157 متر مكعب لمعالجة حمأة مياه الصرف الصحي التي تم جمعها من مشروع مجاري الرستمية. تم فحص خصائص الحمأة الخام من خلال اثنين من المعلمات: تحليل درجة الحموضة ، والمعادن الثقيلة. قدمت جرعات مختلفة من الجير مع الحمأة الخام (0-25) غم من الجير لكل 100 غم من الحمأة. تم خلط العينات يدويًا في أسطوانة دوارة. تم تحليل العينات بعد ساعتين من الخلط. وتمت مقارنة نتائج الرقم الهيدروجيني والمعادن الثقيلة مع وكالة حماية البيئة الامريكية ومسودة التعليمات الوطنية العراقية. أظهرت النتائج عند إضافة الجير ، ينخفض تركيز المعادن الثقيلة. كلما زادت الجرعة ، قل تركيز المعادن الثقيلة في الحمأة على الرغم ان تركيز المعادن الثقيلة في الحمأة كان ضمن المحددات حسب وكالة حماية البيئة الامريكية حيث أظهرت النتائج أن 750غم من الجير لكل 3 كغم من الحمأة خفضت تركيز المعادن الثقيلة(الزنك من(662.934) ملغم / كغم حمأة الى (452.998) ملغم / كغم حمأة -النحاس من (113.101) ملغم / كغم حمأة الى (64.981) ملغم / كغم حمأة – الرصاص من (91.215) ملغم / كغم حمأة الى (53.307) ملغم / كغم حمأة –النيكل من (107.257) ملغم / كغم حمأة الى (50.478) ملغم / كغم حمأة –الموليبديوم من (13.743) ملغم / كغم حمأة الى (8.724) ملغم / كغم حمأة). كانت الجرعة 450 غم من الجير لكل 3 كغم من الحمأة كفيلة بتقليل تركيز الكروم من (110.577) ملغم / كغم حمأة الى (0) ملغم / كغم حمأة.

الكلمات الرئيسية : محطات معالجة مياه الصرف الصحي ، حمأة مياه الصرف الصحي ، المواد الصلبة الحيوية ، المعادن الثقيلة ، الجير.

1. INTRODUCTION

Sewage sludge, a byproduct of the biological wastewater treatment process, is the insoluble solid residue remaining after sewage treatment. Its moisture content is high, as much as 95–97% for primary sludge and more than 99% for excess activated sludge **(Carrère, et al., 2010)**. The characteristics of sewage sludge depend on wastewater and sludge treatment processes (**Jelic, et al., 2011)**. Sewage sludge produced at different plants exhibits great variability in its chemical composition (**Karvelas, et al., 2003)** and **(Tytła, et al., 2016)**. Generally, sewage sludge is composed of a wide range of organic compounds, macronutrients, micronutrients, non-essential trace metals, organic micropollutants, and microorganisms **(Singh and Agrawal, 2008)** and **(Ozcan, et al., 2013)**. Sludge is rich in organic matter and nutrients (N, P) for plant growth, which suggests whether it can be used as a good fertilizer in agricultural applications. Sewage sludge contains heavy metals such as Zn, Cu, Ni, Pb, Cd, Cr, Hg, and persistent organic pollutants (POPs) such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) **(Zennegg, et al., 2013)** and **(Hung, et al., 2015)**. These contaminants may come from industrial wastewater and/or rainwater runoff, which enter into the combined drainage system **(Tytła, et al., 2016)**. Their presence is the main obstacle for the use of sewage sludge in the natural environment **(Lijklema, et al., 1993)**. Various technologies have been developed to transform these hazardous substances into non-toxic forms or reduce their potential release into the environment **(Fernández, et al., 2009)** and **(Rizzardini and Goi, 2014)**. Due to rapid increases in urban population, sewage sludge (biosolids) have increased dramatically in the past 20 years (**Ibrahim, et al., 2015)** so the safe disposal of sewage sludge has become one of the significant environmental concerns throughout the world (**Singh and Agrawal, 2008)**.

2. MATERIALS AND METHODS

2.1 Tank Design

A cylindrical tank was designed as a horizontal rotating drum (125 cm long and 40 cm in diameter) containing four adjacent rooms. Each room contains an opening of 13 cm in diameter, as shown in **Fig. (1.A, and B).** The tank was made of carbon steel. Inside walls were painted with epoxy to avoid corrosion. Electronic pH meters were fixed on the outside surface while their probes were inserted in each room inside the rotating tank. Different mass ratios of sludge and lime were introduced to the rotating tank to ensure complete mixing in a closed system.

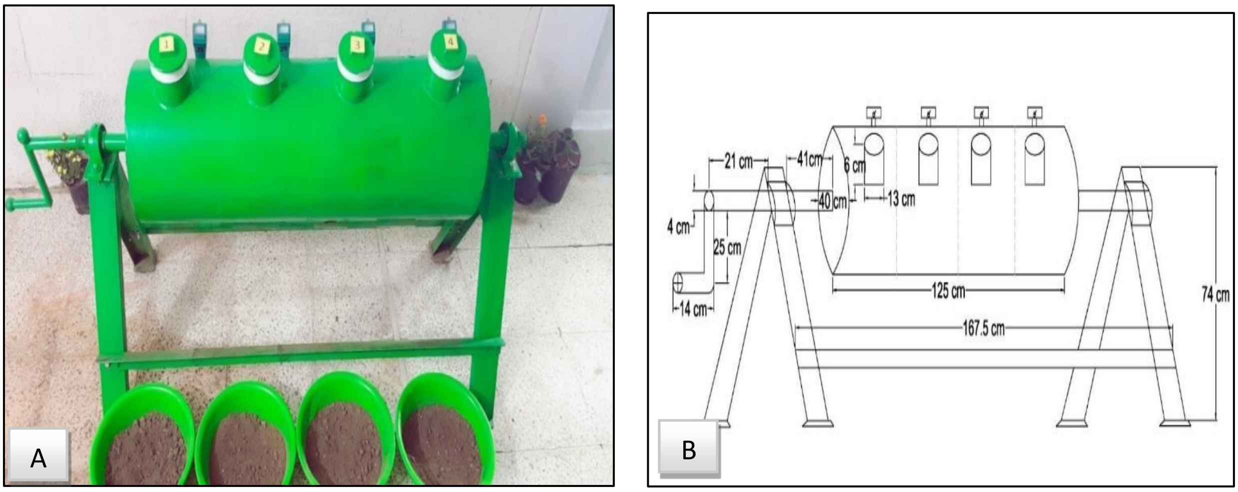

Figure 1. (A) Rotating Mixing Tank **(B)** A Schematic Diagram of the Rotating Mixing Tank

2.2 Raw Materials

Raw dewatered sludge samples were collected from the drying bed units of Al-Rustemiyah Wastewater Treatment Plant using plastic containers fitted with a tight lid and stored in an isolated cool area. The characteristics of raw sludge were examined through pH and heavy metals analysis. Results were reviewed and compared with National Iraqi Standard **(Iraqi Chronicle, 2016)** and EPA's 40 CFR Part 503 regulations for land application **(EPA, 1994)**. Sample containing (0, 1, 2, 3, 4, 5, 15, 25) g lime for each 100 g sludge were prepared and introduced into the four chambers of the rotating tank consequently as listed in **Table 1.**

Table 1. Mass of Sludge to Lime wt./wt.

Lime/sludge	Actual weight of lime kg
0 g lime /100g sludge	0
1 g lime/100g sludge	0.03
2g of lime/100g sludge	0.06
3g of lime/100g sludge	0.09
4g of lime/100g sludge	0.12
5g of lime/100g sludge	0.15
15g of lime/100g	0.45
25g of lime/100g	0.75

2.3. Analytical Procedure (Characterization of the biosolids)

2.3.1 pH

pH analysis becomes a necessary parameter since sludge is going to be used as a compost on agricultural lands. As lime addition is for sterilization purposes, pH should be raised to reach 12 or/and slightly more **(Yurtsever, 2005).**

2.3.2 Heavy metals

Sewage sludge contains trace elements, including heavy metals, primarily from industrial, commercial, and residential discharges into the wastewater system. Trace of heavy elements is required in small amounts by plants or animals **(Tytła, et al., 2016)**. Heavy metals are a group of elements found in the periodic table with relatively high molecular weight and, if had been taken into the body, can accumulate in specific body organs **(Eipstein, 2002).** Heavy metals may be divided into two groups. The first group is zinc, copper, nickel, and chromium that are phytotoxic and can affect crop growth. The second is lead, cadmium, mercury, and molybdenum that are usually not toxic to plants but may be harmful to animals that ingest the treated crops. There must be a balance between metals input and output so that no accumulation occurs on agricultural land. There are other sources of metals that contribute to metals deposition on areas such as atmospheric deposition, manure from stables, and artificial fertilizer **(Dinel, et al., 2000).**

3. RESULTS AND DISCUSSION

3.1 pH

pH was kept above 12 for a 2-hour contact time **(US EPA, 1994)**. pH was recorded through the following frequencies:

- just after liming, at time 0
- 2 hours later
- 24 hours later

The pH of raw sludge was 6.8 as an average reading. Results showed that (30, 60, and 90) g lime/3 kg sludge dosages were not sufficient, keeping pH over 12 for 24 hours. While the best dosage for pH variation was found to be 120 g /3 kg sludge, as shown in **Fig.2**.

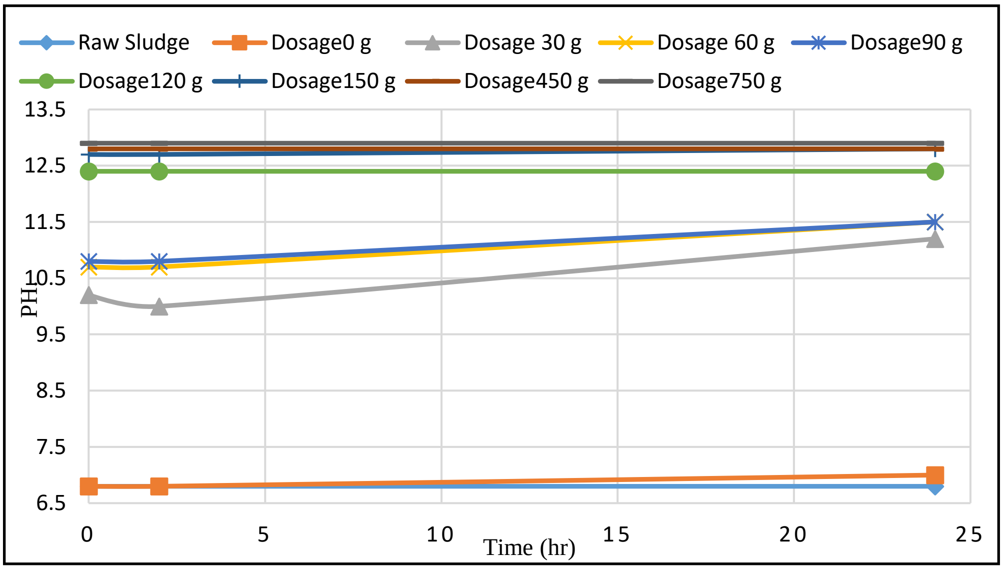

Figure 2. pH Variations vs. Lime Dosage.

3.2 Heavy metals

Heavy metal concentrations in biosolids must meet national standards. The importance of limiting their concentration is based on the possibility of their piling up in soils and thus submitting toxicity and bioaccumulation in edible crops.

3.2.1 Variation in Heavy Metal Concentrations

The data for (zinc, copper, chromium, lead, nickel, and molybdenum) concentrations are represented in **Figs. (3, 4, 5, 6, and7).** Heavy metals concentrations were analyzed using Thermo scientific 900 heavy metals analyzer. Heavy metals concentration was quite low compared with the EPA regulations and National Iraqi Standard. Metals concentration decreased as more lime was added. This doesn't imply that total heavy metals lime-stabilized sludge would be less than that in raw sludge. However, in fact, heavy metals concentration didn't decrease, but total sludge dry weight increased as was mentioned **(Rizzardini and Goi, 2014)**.

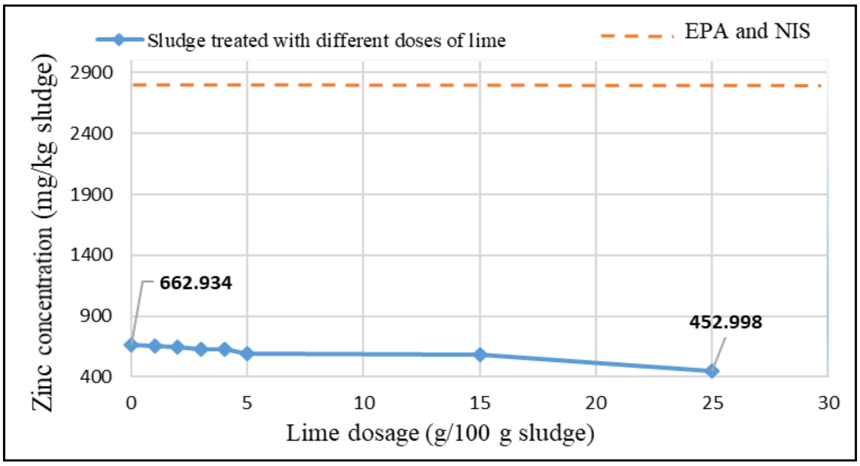

Figure 3. Zinc Concentration vs. Lime Dosage**.**

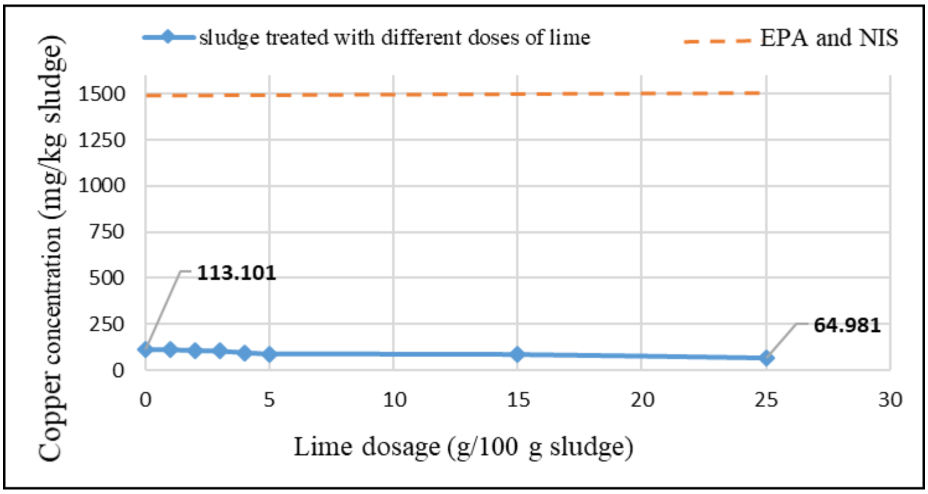

Figure 4. Copper Concentration vs. Lime Dosage.

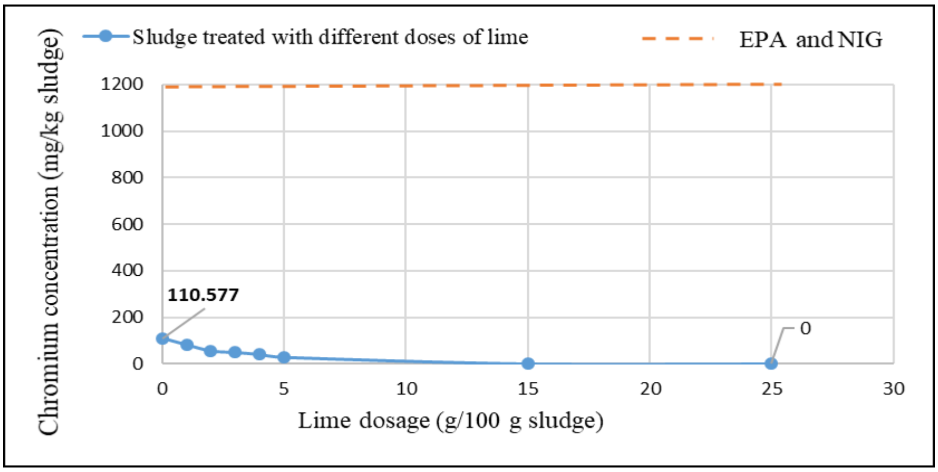

Figure 5. Chromium Concentration vs. Lime Dosage**.**

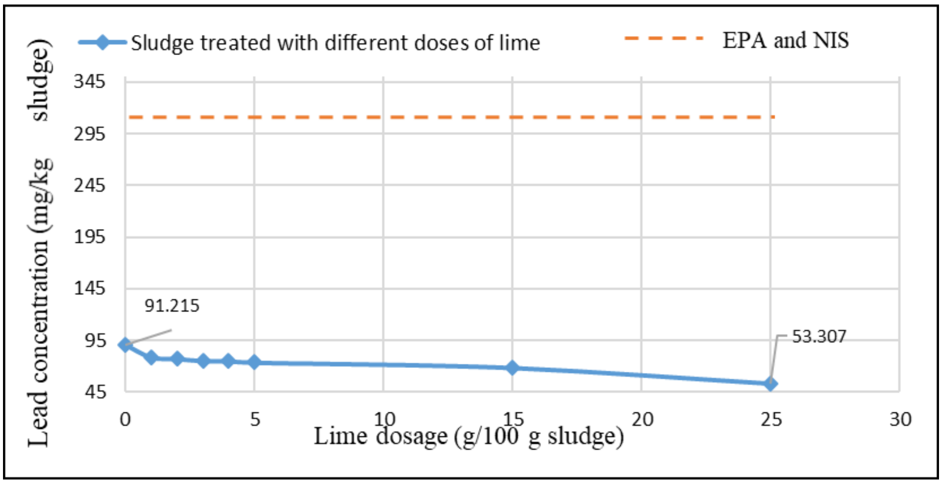

Figure 5. Lead Concentration Variation in Samples

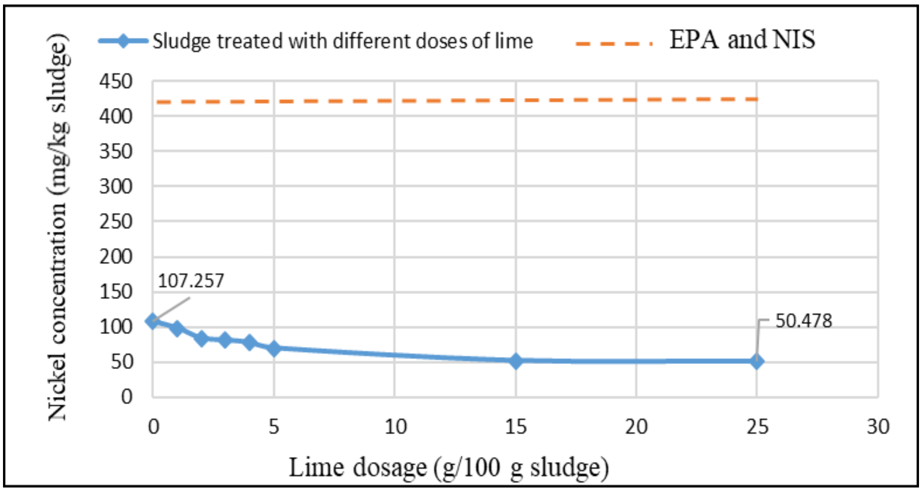

Figure 6. Nickel Concentration vs. Lime Dosage.

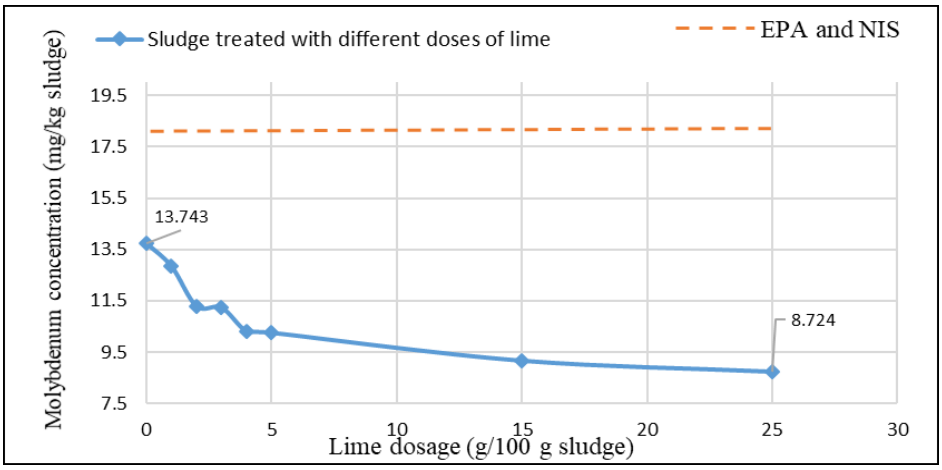

Figure 7. Molybdenum Concentration s. Lime Dosage.

The removal efficiency was calculated for each ion as listed in **Table 2**.

Table 2. Removal Efficiency of heavy metals.

Heavy metals	Efficiency % *
Zinc	31.66
Copper	42.54
Chromium	1
Lead	41.55
Nickel	52.93
Molybdenum	36.52

$$* \frac{conc.before\ added\ lime\_conc.after\ added\ lime}{conc.before\ added\ lime} \times 100$$

4. CONCLUSIONS

Management of sewage sludge the byproduct of the biological wastewater treatment process is becoming increasingly difficult due to the presence of heavy metals. Reliable criteria of US EPA indices and National Iraqi Standard have been relied upon to compare heavy metals of biosolids in Al-Rustemiyah WWTP. Raw sludge pH values were within the range of 6.8-6.9, with an average reading of 6.85. Lime addition increased the pH to 12.9. The concentration of heavy metals as (zinc, copper, chromium, lead, nickel, and molybdenum) was reduced after the addition of lime. However, it was low in raw samples and were within the allowable limits as determined by the United States Environmental Protection Agency and national regulations. Still, lime had reduced their concentration further. The research proved that the best dose of 750 grams of lime per 3 kg of sludge gave the best removal of heavy metals.

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