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TECHNICAL NOTE

Effect of Liquid Waste on the Index and Engineering Behaviour of Cohesive Soils

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Key words

Tannery Effluent, Dye Effluent, Contamination, Physico-Chemical, Consolidation and Double Layer Thickness.

Abstract: The soil-waste interaction can affect the index and engineering properties and thus can lead to land slides, ground subsidence, foundation instability etc. The rate of ground contamination is greatly depends on the type of waste, soil and duration of contamination, other factors like pH, temperature, concentration of ions in waste and production of waste. This paper presents the effect of tannery and dye effluent waste on the index and engineering behaviour of two different soils. The results indicate that the index properties and unconfined compressive strength decreases with increasing period of contamination and the compressibility increases with increasing period of contamination. The coefficient of permeability increases with increasing period of contamination.

Introduction

Industrialisation is inevitable for the developing countries. Due to rapid growth of industries, the disposal of liquid and solid waste onto the ground is becoming a routine and which is cheap disposal method. The leachates generated out of these waste disposals, infiltrates into the ground and causes severe environmental hazards such as ground water contamination, degradation of soil fertility. The contamination of soil not only affects the environment but also leads to serious distress in the existing structures such as pavement, buildings-foundation, underground pipe line, culverts etc. Thus, the changes in the soil behaviour (caused by ground contamination) are one of the major concern for Civil Engineers.

In this connection, the present investigation is intended to study the effect on index properties, compressibility behaviour and shear strength of two different soils with two different effluents for different period of contamination. Olson and Mesri (1970) investigated the influence of electrolyte concentration of sodium chloride and calcium montmorillonite. Bowders and Daniel (1987) investigated the variations in hydraulic conductivity during contamination. Rao and Sridharan (1987) investigated the performance of clay liners on chemical permeation and they reported the interaction mechanisms of various contaminates with clays. Janardanam et al. (1989) studied the changes in permeability of magnesium montmorillonite and kaolinite clay caused by the reaction with permeants. Srivastava et al. (1994) studied the interaction behaviour of a typical alluvial soil and waste-water from a fertilizer plant. Krishnaswamy et al. (1995) investigated the effect of chrome effluent on three different types of cohesive soils and they observed that soil properties and related parameters changes rapidly with pore fluid concentration and its chemical composition.

All these studies show that the effect of effluent on the soil is time bound and magnitude of modified properties depends on type of soil, nature of effluent and duration of leaching period. The materials are selected such that both type of soil and nature of effluent varied.

Materials and Methods

Materials

Since the soils mostly affected by contaminants are fine grained, two clay samples drawn from sites in Chennai, India, were selected for the present study. The sites were selected in such a way that the the natural soil present there were not already contaminated by any effluent. The soils sample thus collected were air dried at room temperature and there after soil lumps were powdered and sieved through 425 μm sieve before using the same for laboratory tests.

The soil S1 collected from Taramani, Chennai at a depth of 1 m from ground level is black in colour. The natural moisture content of this soil was found to vary from 7% to 8%.

Soil S2 was collected from CPT Campus, Chennai at a depth of 1.5 m from ground level by making an open trench. The soil was brown in colour. The natural moisture content was found to vary from 10% to 12%. The details of properties of soil (1) and Soil (2) are summarized in Table 1.

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Table 1 Physical Properties of Soils S_1 and S_2

Soil Description	Particle size distribution				Specific gravity (G)	Atterberg Limits %			Shrinkage Limit (%)	DFS (%)	Max. Dry Density (gm/cm³)	OMC (%)	IS Classification
	Gravel	Sand	Silt	Clay		W_L	W_P	I_P					
S_1	2	15	36	47	2.60	41.0	21.0	20.0	15.3	55.6	1.77	16.6	CI
S_2	4	42	14	40	2.65	52.6	12.7	39.9	8.4	70	1.71	18.1	CH

Two types of industrial effluents were collected namely from tannery and dyeing industries located near Chennai and Coimbatore in India. The effluent were collected from the storage ponds and were brought to the laboratory in tightly closed plastic cans. The effluents thus collected were filtered through Whatman No.41 filter paper to remove the suspended matter. The effluents were then kept in humidity chamber adjusted to 65% humidity. The chemical analysis of the industrial effluents was carried out in the laboratory using standard procedures and the characteristics of the effluents are presented in Table 2.

Table 2 Chemical Analysis of Effluents

Parameters	Tannery Effluent	Dyeing Effluent
p^H Value	8.2	8.0
Chloride, ppm (cl^-)	3200	2450
Sulphate, ppm $(SO_4)^{2-}$	520	400
Phosphate, ppm$(PO_3)^{3-}$	100	82
Chromium, ppm (Cr^+)	65	38
Potassium, ppm (k^+)	52	30
Calcium, ppm (Ca^{2+})	218	120
Magnesium, ppm (Mg^{2+})	150	120
BOD, ppm	30	20
COD, ppm	100	80

Methods

Test were conducted for determining index properties, unconfined compressive strength and consolidation behaviour of untreated and effluent contaminated soil samples. To Study the influence of industrial effluents on the properties of soil, the soil was artificially contaminated by adding 25% of different effluent (by weight of soil) to each soil sample. Since the period of contamination is an important variant with respect to the variations in the properties of soil, the elapsed time intervals of contamination for 15 days 30 days and 45 days were selected for the study. The adequate quantity of soil sample mixed with the effluent was taken out immediately after the selected elapsed time interval and was subjected to various testing. The effluent treated soil samples were kept in a constant humidity using a humidity control device. The properties of the contaminated samples are determined as per IS standard applicable to engineering soils.

Results and Discussion

Effect on Index Properties

Liquid and plastic limit

Figure 1 shows the variation of liquid limit with different period of contamination for both the soils. Liquid limit decreases with increase in duration of contamination period. The rate of decrease in liquid limit by increasing contamination period is relatively small in the case of tannery effluent compared to dyeing effluent. However the difference is not much significant for soil (2).

Liquid limit is a function of clay content and generally as clay content increases liquid limit also increases. The mechanism controlling liquid limit and plastic limit has been related to physical and physico-chemical forces those depend on the type of minerals (Sridharan and Venkatappa Rao, 1975).

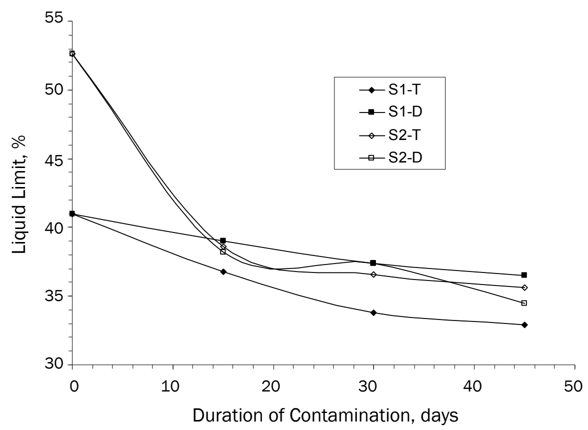

Fig. 1 Variation of Liquid Limit with Duration of Contamination

The reduction in liquid limit may be attributed to the reduction in thickness of diffused double layer. The presence of monovalent potassium ions and divalent calcium and magnesium ions (potassium 52 ppm, calcium 218 ppm and magnesium 150 ppm for tannery effluent. while potassium 30 ppm, calcium 120 ppm, and magnesium 120 ppm for dyeing effluent) in the effluent may be influencing the structural arrangement of the soil by which the liquid limit decreases. The reduction of liquid limit is much significant for soil (2) than soil (1).

Figure 2 shows the variations of plasticity index with respect to duration of contamination for both soils. As in the case of liquid limit, the plasticity index also decreases with increasing contamination period.

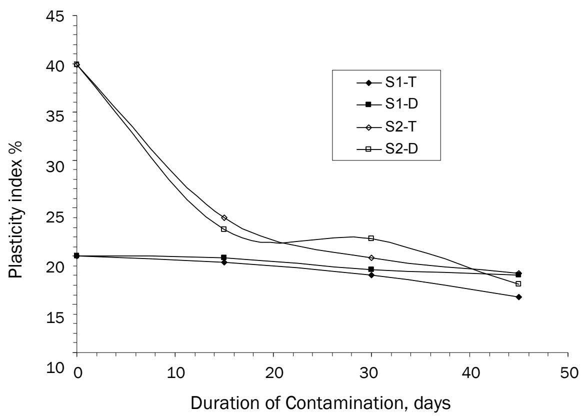

Fig. 2 Variation of Plasticity Index with Duration of Contamination

Shrinkage limit

Shrinkage limit is an indicative to the swelling nature of any soil. In general higher the shrinkage limit value lower would be the shrinkage potential and such soil will be of low swelling nature.

Figure 3 shows the variation of shrinkage limit with varying period of contamination of both soils. The shrinkage limit is increasing with increasing contamination period for both the soils (1) and (2). However, the shrinkage limit is initially decreasing for soil (1) contaminated with dye effluent, while the plasticity also reduced during the period. The increase in shrinkage limit is always more for tannery effluent contaminated soil than that contaminated by dye effluent.

In general, the soils with flocculated structures shrink less than that with a dispersed structure (Sridharan 1990). The increase in shrinkage limit may also be attributed to the corresponding change in the soil structure due to diffused double layer.

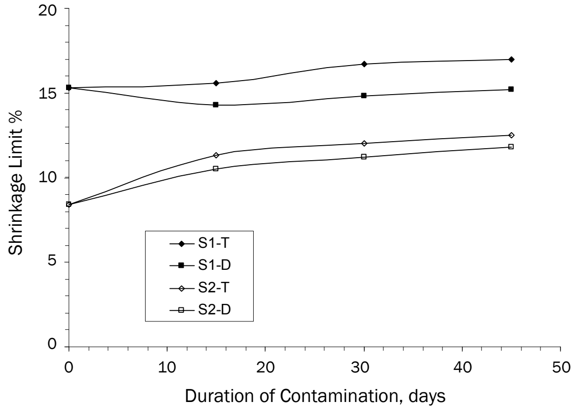

Fig. 3 Variation of Shrinkage Limit with Duration of Contamination

Free swell index

The free swell index is a very important for identification of swelling nature of the soils.

Figure 4 shows the variation of differential free swell and duration of contamination. It is seen that for both the soils the differential free swell decreases with increasing duration of contamination period.

Sridharan and Rao (1985) brought out the mechanism governing swelling of expansive clay that is primarily by diffuse double layer repulsion forces and this physico-chemical force will be dominating more for montmorillonitic types of soils and the same force less significant for kaolinite type of soils. Generally soil with flocculated structure occupies lesser sediment volume compared to disperse structure (Sridharan 1990). In the present case, influence on soil structure for both cases at any period of contamination is reflected in the form of sediment volume reduction with increasing period of contamination. The soils seem to flocculate by contamination.

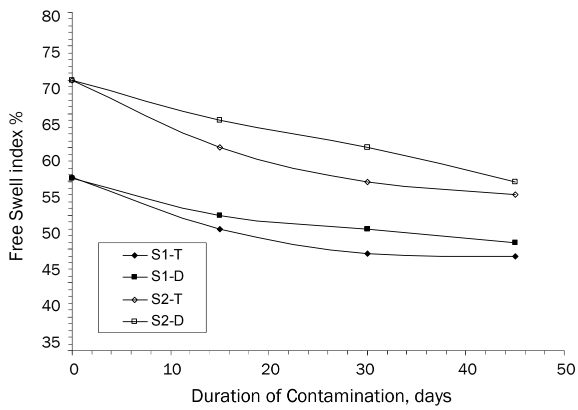

Fig. 4 Variation of Free Swell Index with Duration of Contamination

Effect of Effluent on the Unconfined Compressive Strength

Specimens for shear strength tests were prepared immediately after mixing with the contaminant with the soils and the test specimens were kept in the humidity control device. The tests were conducted at different period of contamination. Figures 5 and 6 show the stress strain relationship of soil (1) with tannery and dye effluent. It is observed that the peak strength decreases with increasing contamination period for both the soils and the initial tangent modulus also is found to be decreasing with duration of contamination irrespective of type of effluents. This indicates that the soil became weaker by contamination. The contamination by tannery effluent has more influence on the strength reduction.

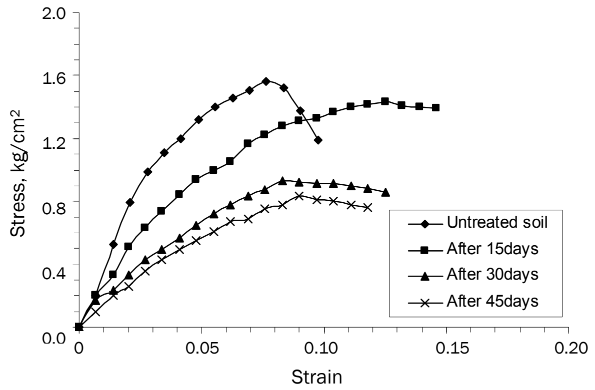

Fig. 5 Stress Strain Characteristics of S_1 with Tannery Effluent

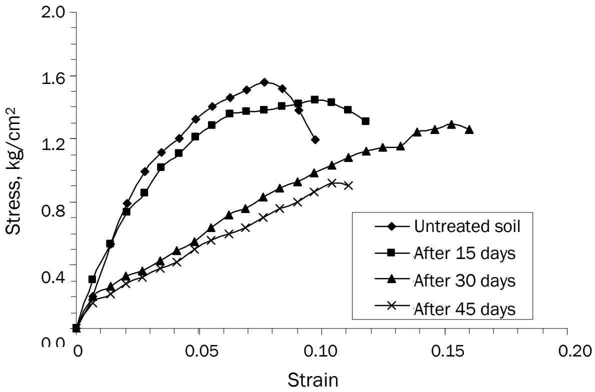

Fig. 6 Stress Strain Characteristics of S_1 with Dye Effluent

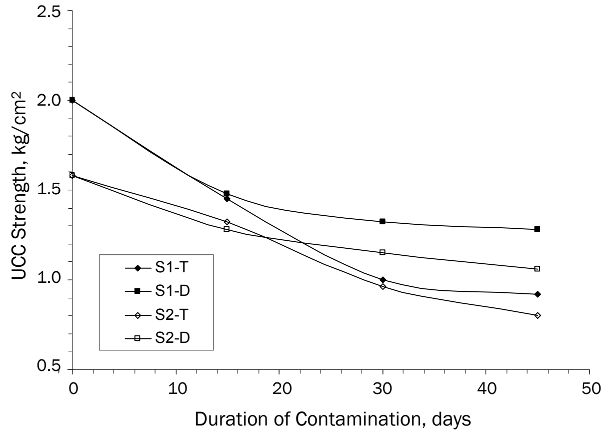

Fig. 7 Variation of UCC Strength with Duration of Contamination

Figure 7 shows the variation of UCC strength with duration of contamination for both the soils (1) and (2). In general, soil with flocculated structure will be offering higher shear strength than soil with the same density but having a dispersed structure. Accordingly one would expect an increase in unconfined compressive strength when the soil assumes flocculated structure. In the present case, the UCC strength decreased with increased contamination period for both cases. The reduction in UCC strength is expected to be due to the change in the soil structure under increasing contamination period.

Effect of Effluents on the Consolidation Behaviour

In order to understand the consolidation behaviour of effluent treated soils, the soil samples are prepared at the liquid limit consistency. These specmines were also prepared after mixing the effluent. From the consolidation test, initial, primary and secondary compressions, co-efficient of consolidation, co-efficient of permeability and compression index are calculated and the results are discussed below.

Coefficient of Consolidation

Table 3 and 4 shows the variation of co-efficient of consolidation c_v for the pressure increment of 0.4 – 0.8 kg/cm², 0.8 – 1.6 kg/cm², 1.6 – 3.2 kg/cm² and 3.2 – 6.4 kg/cm² with different duration of contamination for both the soils. For the same pressure increment, the c_v is found to increase with increase in duration of contamination. Increase in initial compression with increase in duration of contamination is also observed

Table 3 Effect of Effluent on the Consolidation Behaviour of S_1

Sample Description	Compression Index (c_c)	Co-efficient of consolidation c_v (cm²/sec)			
		At pressure range, kg/cm²			
		0.4 – 0.8	0.8 – 1.6	1.6 – 3.2	3.2 – 6.4
S_1	0.30	2.90X10^{-4}	4.95x10^{-4}	4.40x10^{-4}	1.37x10^{-4}
S_1T_{15}	0.31	6.50X10^{-4}	6.80x10^{-4}	8.64x10^{-4}	1.03x10^{-4}
S_1T_{30}	0.20	3.58X10^{-4}	4.19x10^{-4}	6.30x10^{-4}	8.65x10^{-4}
S_1T_{45}	0.23	2.78X10^{-4}	3.32x10^{-4}	4.13x10^{-4}	5.32x10^{-4}
S_1D_{15}	0.23	3.64X10^{-4}	8.27x10^{-4}	7.00x10^{-4}	8.40x10^{-4}
S_1D_{30}	0.25	2.91X10^{-4}	3.60x10^{-4}	4.21x10^{-4}	3.80x10^{-4}
S_1D_{45}	0.27	8.18X10^{-4}	6.47x10^{-4}	6.53x10^{-4}	5.22x10^{-4}

Table 4 Effect of Effluent on the Consolidation Behaviour of S_2

Sample Description	Compression Index (c_c)	Co-efficient of consolidation c_v (cm^2/sec) At pressure range, kg/cm^2			
		0.4 – 0.8	0.8 – 1.6	1.6 – 3.2	3.2 – 6.4
S_2	0.35	8.64X10^{-5}	6.890x10^{-5}	2.310x10^{-4}	9.620x10^{-5}
S_2T_{15}	0.23	8.46X10^{-5}	6.890x10^{-5}	2.310x10^{-4}	9.620x10^{-5}
S_2T_{30}	0.33	1.613X10^{-4}	2.450x10^{-4}	1.840x10^{-4}	1.750x10^{-4}
S_2T_{45}	0.31	1.470X10^{-4}	7.420x10^{-5}	1.240x10^{-4}	9.230x10^{-5}
S_2D_{15}	0.30	1.428X10^{-4}	1.151x10^{-4}	1.350x10^{-4}	1.182x10^{-4}
S_2D_{30}	0.39	1.346X10^{-4}	9.300x10^{-5}	3.720x10^{-4}	3.283x10^{-4}
S_2D_{45}	0.35	1.740X10^{-4}	1.205x10^{-4}	1.152x10^{-4}	8.830x10^{-5}

for any pressure increment. The variation of the initial compression supports the variation of c_v with duration, of contamination. Normally the soil with high c_v, will have more initial compression. The contaminated soils have more c_v indicating more initial compression attributable to coarser materials. The variations of index properties have been explained as due to formation of flocculated structure. The proposed mechanisms support the variation of c_v and initial compression. The soil with flocculated structure will have higher rate of settlement.

Void ratio – Pressure Relationship

The void ratio- pressure relationship for both cases is shown in Figures 8 to 11. The one dimensional consolidation samples were prepared at their respective liquid limit consistency. The void ratio has fairly linear relationship with pressure. The compression index values are calculated from e-log p curve from 0.2 kg/cm^2 onwards wherein the curve is linear. The c_c thus obtained is summarized in Table 3 and 4. The compression index is decreasing with duration of contamination period for both the cases irrespective of

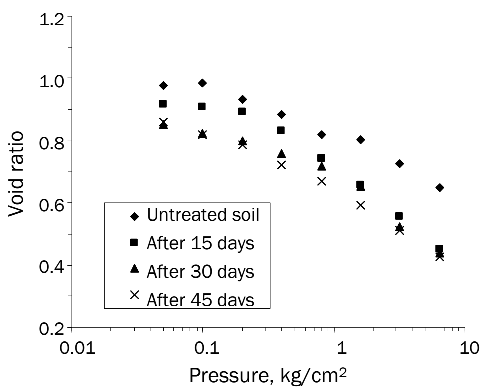

Fig. 8 Void Ratios vs. Pressure Relationship for S_1 with Tannery Effluent

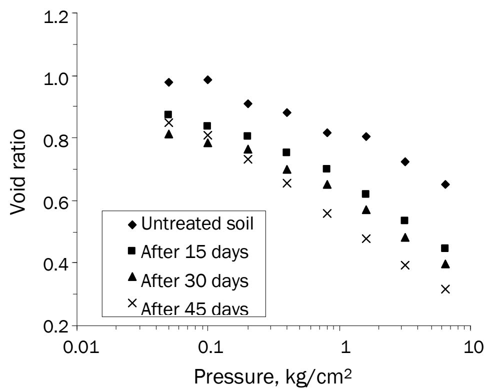

Fig. 9 Void Ratios vs. Pressure Relationship for S_1 with Dye Effluent

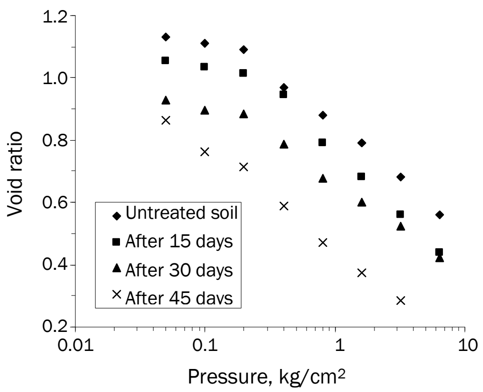

Fig. 10 Void Ratios vs. Pressure Relationship for S_2 with Tannery Effluent

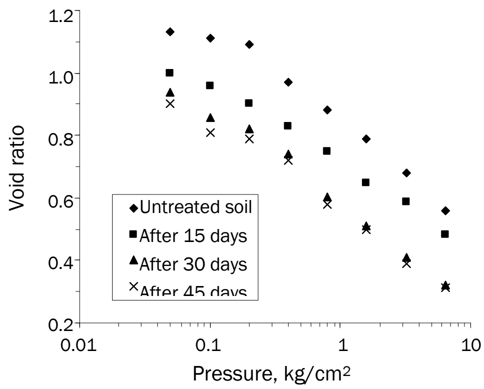

Fig. 11 Void Ratio Vs Pressure Relationships for S_2 with Dye Effluent

type of effluents. Such behaviour is expected as the initial compression is increasing with contamination period and also by the fact the liquid limit and the plasticity index values are decreasing with contamination period.

Coefficient of permeability

The co-efficient of permeability values are calculated from the following relationship $k = c_v m_v \gamma_w$ The values of k calculated for different void ratio is shown in Figure 12. For the same void ratio, the coefficient of permeability increases with duration of contamination

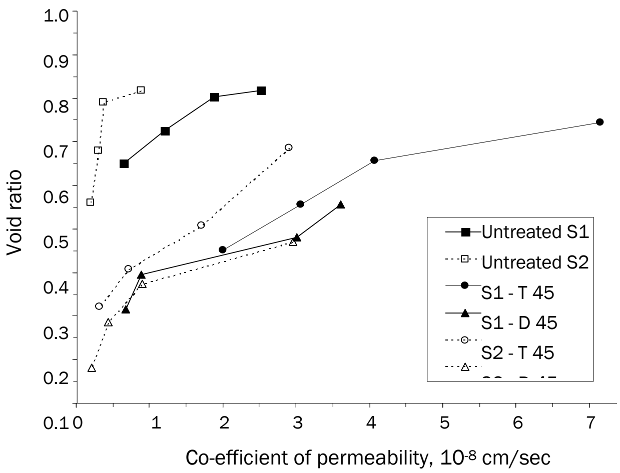

Fig. 12 Variation of k with Duration of Contamination

for both the soils. The co-efficient of permeability of soil with flocculated structure will be higher than dispersed structure (Mitchell 1976). As explained in the preceding sections, the flocculated soil structure results increase in coefficient of permeability with increasing contamination period.

Conclusions

The following major conclusions are arrived from the study:

- The liquid limit and plasticity index values are found to be decreasing with increasing period of contaminations for both soil (1) and soil (2). The decrease is higher for tannery effluent than dye effluent. The decrease in the liquid limit is due to reduction in the double layer thickness of clay particles. However, for soil (1) the liquid limit changes are marginal. The shrinkage limit is also marginally changes for both soil (1) and (2).
- The unconfined compressive strength decreases with increasing duration of contamination of both the soils.
- Generally the c_c value decreases with increasing duration of contamination for both soils with tannery effluent, while the c_c is increasing with increasing duration of contamination by dye effluent for both the soils. The initial compression increases for the contaminated soil, while the consolidation settlement reduces.
- The c_v value increases with increasing contamination period for both soils for any pressure increment.
- The k value increases for the same void ratio with increasing period of contamination for both soils.

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