Bangladesh J. Soil Sci. 2025, 41 (1): 147-158

MINERALOGICAL COMPOSITION OF SOME SOILS FROM GOPALGONJ KHULNA BEEL OF BANGLADESH

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Abstract

Total land area of Bangladesh consists of 30 Agro-ecological regions (AEZs) and the most of the applied agricultural research is being conducted on this basis. In order to provide basic information of applied research an attempt was made to study the mineralogy of important soils from all AEZs of Bangladesh. The mineralogical composition of eight soil samples from two representative soil series, namely Satla and Harta from AEZ 14, Gopalganj Khulna Beel has been reported in this paper. According to USDA textural class system four soil samples were silt loam, three were silt and only one was sand. Overall, the <2 μm clay fraction of both soils was dominated by mica ranging from 31 to 69% followed by smectite, kaolinite and chlorite minerals. Layer silicates, quartz and feldspar minerals were also present in Satla soils. In Harta soil, the dominant minerals were mica and smectite. The findings of the present study support the mineralogical Suite of mica-smectite for this AEZ.

Keywords: Clay mineralogy, Gopalganj Khulna Beel, Harta series, Salta series, Smectite

1. Introduction

Agriculture is the mainstay of Bangladesh economy, accounting for 11.6% GDP where crops sub-sector alone contributes 7.25% (WB, 2022). It is the important driver of growth and rural development, extends employment opportunities for more than 40% of the country's workforce and supplies raw materials to the industries. Bangladesh has a wider range and greater complexity of lands. Earlier, soils of Bangladesh were divided into 7 tracts, then into 21 General Soil Types and 537 soil series (Hussain, 2020). At present the country has been divided into 30 Agro Ecological Regions (AEZ) (FAO-UNDP, 1988). Nevertheless, agricultural research, and technology innovation and transfer are mostly based on the AEZ information.

Soil is one of the most important natural resources. These huge sediments are the major sources of formation of 80% soils of the country. The remaining 20% of soils have been formed in Tertiary and Quaternary sediments of hills (12 %) and in uplifted Pleistocene Terrace (8%) (Hussain, 2020). Mineralogical study of soil is essential to have an idea about hysico–chemical properties, nutrient behavior as well as inherent potentiality of soils. Considering the above, mineralogy of important soils from all AEZs of Bangladesh were done. As a part of this, the mineralogy of the Gopalgang Khulna Beel (AEZ 14) is reported in this paper.

The AEZ 14 occupies a number of separate basin areas in Madaripur, Gopalganj, Nariel, Jashore, Bagherhat and Khulna districts covering 2247 km2 area. Soil physiography is almost level, low laying basin occupy most of the region, with two ridges along rivers and cracks. On basin margins grey and dark grey acidic heavy clay overlies peat and muck at 25-100 cm. Soft peat and muck occupy perennially wet basin centers. Organic matter content is medium (1.7-3.4%). Communications in the beel area is very difficult except by boat. Moslehuddin et al. (1999) placed AEZ 14 (Mc-St suite) in mica-smectite* suite while preparing a tentative mineralogical map of Bangladesh, indicating mica and smectite were the medium (FAO-UNDP, 1988). Some vermiculite was found. The present study is done to verify the mineralogical map and to get a clear idea about clay mineralogy of this AEZ.

2. Materials and Methods

2.1 Soil Series

Two major soil series were selected from AEZ 14 - Satla and Harta. Three samples were collected from Satla series and five samples from Harta series. The sampling depth was 0 to 15 cm for all samples. The collected soil samples were carried to the laboratory, air-dried at room temperature, mixed thoroughly, crushed, sieved with a 20 mesh sieve and preserved in plastic bags for subsequent laboratory analysis. Some basic information of each soil series are given in Table 1.

2.2 Particle-Size Analysis

For determination of particle-size distribution, l0g of air-dry soil was weighed and 7% H2O2 was added to allow disintegration of organic matter, stirred with a mechanical stirrer, and adjusted to pH 10 using 1 M NaOH. The <2 µm clay fraction was separated with repeated stirring–sedimentation–siphoning. The 2–20 µm clay fractions were separated with repeated sedimentation–siphoning, and 20–53, 53–212, 212–2000 µm fractions were separated by wet sieving. Weight of each fraction was determined to calculate particle–size distribution.

2.3 Determination of pH and EC

Soil pH was determined by glass electrode pH meter. Soil pH was measured in water being soil: water ratio being 1:2.5, after 30-min shaking. The electrical conductivity (EC) of the soils was measured in 1:5 (soil: water) suspension with a glass electrode EC meter as described by Jackson (1988). The results were expressed in dS m-1, after 30-min shaking.

2.4 Determination of exchangeable cations (Na, K, Ca and Mg)

Extractable Na, K, Ca, and Mg contents of soils were determined by taking 2.5g soil samples into a 15ml centrifugal tube. About 8ml of CH3CHOONH4 was added and the tube was shaken for 10 minutes. Then the suspension was centrifuged for 5 minutes at 1500 rpm and the supernatant was decanted and filtered into a 25ml volumetric flask. The process was repeated two more times. Extractable Na and K were determined by flame photometer while Ca and Mg were determined by Atomic Absorption spectrophotometer.

Table 1. Some basic information of each soil series of AEZ 14

Soil Series /Soil Samples	Location	Land type	USDA Taxonomy	Land Use
Harta 1	Vill: Garolgoti Union: Bohugram Upazila: Muksudpur Dist: Gopalganj	Level Land	AericFluvaquents	Grass pea – Jute – Fallow
Satla 2	Vill: Basuria Union: Uzani Upazila: Muksudpur Dist: Gopalganj	Medium Low Land	Aeric Fluvaquents	Grass pea- Broadcast aus – Fallow
Harta 3	Vill: Hatiara Union: Hatiara Upazila: Kashiani Dist: Gopalganj	High Land	AericFluvaquents	Boro-Fallow-Fallow
Satla 4	Vill: Andharkota Union: Shinga Upazila: Kashiani Dist: Gopalganj	Very Low Land	Aeric Fluvaquents	Grass pea- Broadcast aus – Fallow
Satla 5	Vill: Chondrodigholia Union: Chondrodigholia Upazila:Gopalganj sadar Dist: Gopalganj	Medium Low Land	Aeric Fluvaquents	Grass pea – jute – Fallow
Harta 6	Vill: Mollakandi Union: Nijra Upazila: Gopalganj sadar Dist: Gopalganj	High Land	Aeric Fluvaquents	Boro-Fallow-Fallow
Harta 7	Vill: Rangpur Union: Rangpur Upazila: Dumuria Dist: Khulna	Medium Land	Aeric Fluvaquents	Boro-Fallow-Fallow
Harta 8	Vill: Amvita Union: Raghunathpur Upazila: Dumuria Dist: Khulna	Medium High Land	Aeric Fluvaquents	Grasspea- jute-Fallow

2.5 Mineralogical Analysis of Clay Fraction

2.5.1 Dispersion and separation of clay fraction

To concentrate clay fraction the soils were thoroughly dispersed. To achieve successful dispersion the following pretreatments were used for the removal of flocculating and cementing agents.

 # Removal of carbonates and organic matter: The soil samples were treated with 1N NaOAc-acetic acid buffer (pH 5) to destroy the free carbonates and Organic matter was destroyed by 30% H2O2 treatment (Jackson,1967).

 # Removal of iron and manganese oxides: Free oxides of Fe and Mn were removed from soils by the citrate–bicarbonate–dithionite extraction method, as was described by Mehra and Jackson (1960).

After removing soluble salts, carbonates, organic matter, MnO2 and Fe2O3, the soils were dispersed with 5% Calgon solution and the clay fraction (<2μm) was separated by repeated stirring-sedimentation-siphoning processes (Jackson, 1975).

2.5.2 Preparation of slide and X-ray diffraction analysis

Specimens for XRD of the clay fraction were prepared by taking duplicate clay samples containing 50 mg of clay (<2μm) in 10 ml centrifugal tube. Washing by centrifugation and decantation was carried out twice with 8ml of an equal mixture of 1M NaCl and 1M NaCH3COOH (pH 5.0) in order to decrease the pH of the preserved clay soils. Of the duplicate sets, one was saturated with K and the other with Mg by washing three times with 8 ml of 1M KCl and 0.5M MgCl2, respectively. Excess salt was removed by washing once with water. Clay in the tube was thoroughly suspended with 1ml of water. An aliquot of 0.4 ml of the clay suspension was dropped onto a glass slide (28×48 mm), covering two-thirds of its area, air dried, and X-rayed (parallel powder mount). XRD patterns were obtained using a Rigaku X-ray diffractometer (RINT 2100V, Rigaku) with Ni-filtered CuK radiation at 40kV, 20 mA and at a scanning speed of 2º 2 per minute over a range of 3 to 30º 2 . In addition to the air-dry specimen, the Mg-saturated clay specimen was X-rayed after salvation with glycerol, and the K-saturated clay specimen was x-rayed after heating at 300 and 550 ºC for two hours. Identification of clay minerals was made mainly on the basis of their characteristic basal reflections (C-axis length) (Jackson, 1975). Approximate mineral composition of the <2μm clay fraction was estimated based on the relative peak intensities in the XRD patterns of the random powder mount. The peak intensity was calculated by multiplying peak height with peak width at half height (Moslehuddin and Egashira, 1996). The intensities ratio of two components P and Q in a multi-component mixture can be related to their weight ratio as follows:

Ip/Iq = Kp.q (wp/wq)

Where, Ip and Iq are the intensities of the P and Q components, respectively in XRD; wp and wq are the weight proportion of P and Q components, respectively; and Kp.q, a constant value, is the intensity-weight coefficient of P and Q component (Islam and Lotse, 1986). Since mica was detected in all samples, all the other minerals were paired with mica and the intensity ratios of all the pairs were calculated. With application of appropriate values for Kp.q, the weight ratios of all the pairs were calculated (Egashira and Yasmin, 1990). Assuming that the sum of the weight ratios is one, the weight proportion of all the minerals in the <2µm clay fraction were obtained.

3. Results

3.1 Particle-Size Distribution

Particle-size distribution and follow-up soil texture as determined by the USDA system are shown in Table 2. Each soil sample was fractioned into five groups, viz. <2, 2-20, 20-53, 53-200 and 200-2000 µm. It was observed that the clay (<2µm content) fraction varied widely ranging from 0.4% in Harta to 2 to 6.4% in Satla-2. The <2µm size fractions in four soil samples (Satla-2, Satla-3, Harta-4 and Harta-5) was between 4.4 to 6.4% while others had below 3.3%. The 2-20 µm fractions varied from 5.7% in Harta-2 to 69.8% in Satla-2 soil. The 20-53 µm fractions varied from 1.1% to 27.3% with the lowest value in Harta-2 and the highest value in Harta-1. The sand fraction (53-200 µm) was 6.5% in Salta-3 while it was 17.8% in Harta-4. The coarse sand (200-2000 µm) was found in very negligible to small amounts (0.5%) in Harta-2, and it was higher in amount (10.4%) in Harta-5.

3.2 Soil pH and EC

Soil pH of the eight samples varied from 4.9 to 6.0. Among the different soils, the pH of Harta series varied from 4.9 to 5.9 and that in Satla series ranged from 5.0 to 6.0. The highest pH value of was found in Satla-2 and the lowest pH value in Satla 4 series. Most of the soils are strongly acidic. The EC of the two soil series ranged from 0.11 to 0.74 dS m-1 (Table 3). The soil EC of Harta series ranged from 0.11 to 0.30 dS m-1 and that of Satla series the EC ranged from 0.25 to 0.74 dS m-1. The highest EC value was observed in Harta-3 (0.74 dS m-1) soil while the lowest was in Harta-8 (0.11dS m-1). Most of the soils was non-saline.

Table 2. Particle-size distribution (USDA) and textural classes of soils from two soil series

Soil series	Particle-size distribution (%)					
	<2 µm	2-20 µm	20-53 µm	53-200 µm	200-2000 µm	Textural class
Harta1	3.856	51.670	27.249	14.138	3.084	Silty loam
Satla2	2.480	66.878	14.105	13.618	2.918	Silt
Harta3	0.362	5.724	1.004	92.388	0.522	Sand
Satla4	6.396	69.767	6.976	9.593	7.267	Silty loam
Satla5	4.878	64.498	19.241	6.504	4.878	Silt
Harta6	3.341	62.213	19.206	10.229	5.012	Silt
Harta7	5.257	56.135	13.970	17.780	6.859	Silty loam
Harta8	4.361	57.945	19.691	7.594	10.408	Silty loam

USDA = United States Department of Agriculture

3.3 Exchangeable potassium, sodium, calcium and Magnesium

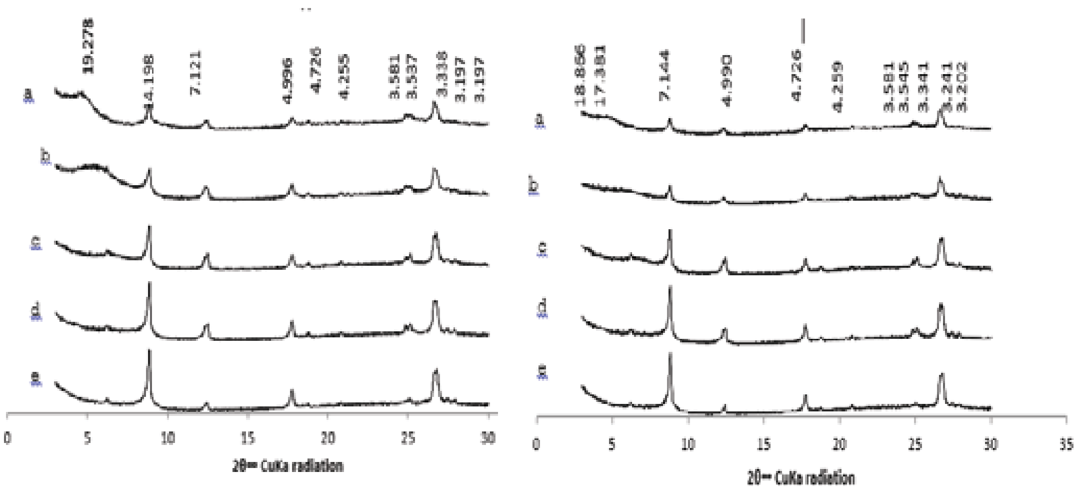
Among the different soils of AEZ 14, Table 3 shows that the exchangeable K ranged between 0.025 and 0.008 cmol kg-^{1} in the Harta Series and that for the Satla Series from 0.025 to 0.014 cmol kg-^{1}. The exchangeable Na in the Satla Series varied from 0.093 to 0.067 cmol kg-^{1}, while in the Harta Series it was 0.078 to 0.073 cmol kg-^{1}. The highest exchangeable N a value (0.093 cmol kg^{1}) was found in Satla-4. The exchangeable Ca was the highest in the Harta-3 series and the lowest in the Harta-8 series. The exchangeable Mg in the Satla Series was found to vary from 5.72 to 3.53 cmol kg-^{1} and in the Harta Series from 5.72 to 2.55 cmol kg-^{1}. The highest value was recorded in Satla-2, and the lowest in Harta-8.

The XRD patterns of the clay (<2 µm) fraction of the Satla-1, Satla-3, Harta-3, and Harta-5 samples are shown in Figure 1. The peaks in most samples are broad, indicating low crystallinity and/or small crystallite size of the minerals, or the presence of mixed-layer minerals. Some peaks are sharp, indicating good crystallinity and/or large crystallite size of the minerals.

Table 3. Soil pH, EC and exchangeable K, Na , Ca and Mg of the selected soil series

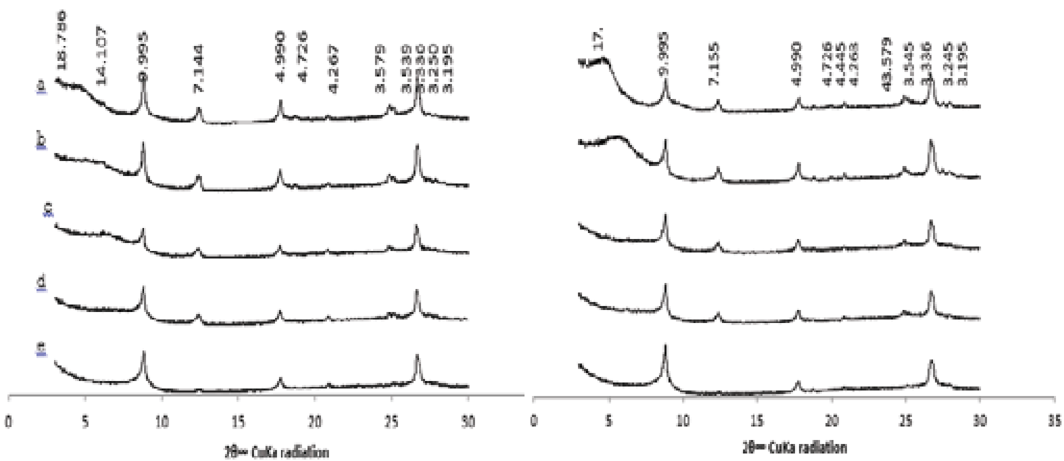
Soil Series	**pH**	**EC** (dS m^{-1})	Exchangeable K (cmol kg^{-1})	Exchangeable Na (cmol kg^{-1})	Exchangeable Ca (cmol kg^{-1})	Exchangeable Mg (cmol kg^{-1})
Satla-1	6.0	0.25	0.013	0.057	26.65	5.720
Satla-2	4.9	0.77	0.014	0.068	25.55	5.630
Satla-3	5.0	0.47	0.022	0.078	30.15	3.105
Hartal-1	5.9	0.3	0.025	0.093	29.70	4.970
Harta-2	5.0	0.74	0.025	0.073	15.25	3.530
Harta-3	4.9	0.50	0.025	0.078	26.95	5.040
Harta-4	5.0	0.47	0.025	0.076	17.05	2.970
Harta-5	5.5	0.11	0.008	0.073	13.80	2.550

The approximate mineral contents of the clay fraction were estimated based on the XRD peak intensities (peak height multiplied by peak width at the half height) of parallel powder mount. Reflections of the Mgsaturated and glycerol-solvated specimen were mainly used to calculate peak intensities of the minerals. Mica was identified by the presence of 10Å peaks, in the Mg-Saturated specimen and these peaks were used for the calculation of their peak intensities. Chlorite was identified by the remaining of the 14.2 Å peak in the K-saturated and 550°C heated specimen while the presence of kaolinite was ascertained by the decrease in the 7.14 Å peak intensity after heating of the K-saturated at 550°C. To measure the intensities of the chlorite and kaolinite, the 7.14 Å peak intensity of the Mg saturated and glycerol solvated specimen was allocated between chlorite and kaolinite according to the intensity ratio of the 3.54Å (chlorite) and 3.57Å (kaolinite) peaks. The presence of smectite was suggested by the broad bulge around 1.80 nm in the Mg-saturated and glycerol solvated specimen. Vermiculite could be identified by the decrease in the intensity of the 14.2 A0 peak with the corresponding increase in the intensity of the 10 Å peak by K-saturation and air-drying, and the vermiculite intensity could be calculated by subtracting the intensity of the 14.2 Å peak of the K-saturated and air-dried specimen from that of the Mg-saturated and glycerol-solvated specimen To identify and calculate the intensities of quartz, feldspars, 4.25, and 3.20Å peaks were used. For calculation of vermiculite intensity 14 Å peak was used after subtracting the intensity due to chlorite but no positive value was obtained in any of the samples.



Satla-1 Satla-3

Fig 1. X–ray diffraction patterns of the <2 μm clay fraction of Satla–1 (left) and Satla–3 (right) soil. Spacing is in Å. Treatments: a) Mg–saturation and glycerol–solvation; b) Mg–saturation and air–drying; c) K–saturation and air– drying; d) K–saturation and heating at 300°C; e) K–saturation and heating at 550°C.



Harta-3 Harta-5

Fig. 2 X–ray diffraction patterns of the <2 μm clay fraction of Harta–3 (left) and Harta–5 (right) soil. Spacing is in Å. Treatments: a) Mg–saturation and glycerol–solvation; b) Mg–saturation and air–drying; c) K–saturation and air–drying; d) K–saturation and heating at 300°C; e) K–saturation and heating at 550°C.

Approximate mineral composition of the clay fraction (<2 μm) was estimated based on the relative peak intensities of the respective minerals in the XRD charts following Moslehuddin and Egashira (1996) was presented in Table 4. In clay fractions, six different minerals, i.e., mica, smectite, chlorite, kaolinite, feldspars, goethite and quartz were found in the studied soils (Table 4). Mica was found as the most predominant mineral in all the soil samples ranging from 31-69%, the highest value was found in Satla-5 series and the lowest was in Hatla 8 series. Next to mica, smectite is the second dominant mineral ranging from 3-45%. Chlorite and quartz were present in good amounts than other minerals ranging from 4-8% and 9-16%, respectively. Presence of chlorite and feldspar were low ranging from 3-8% and 2-9% respectively.

4. Discussion

Particle-size distribution showed that most of the soils were predominantly medium-textured, with silt loam to silt textural classes, except for Harta-3, which was classified as sand. The sand content was high in only one sample, while three other samples had silt and four samples had silty loam textures. The data on pH of the soil samples under study indicated that, according to BARC (2012), all samples were strongly to slightly acidic in nature, with pH values ranging from 4.9 to 6.0. The pH values obtained in this study were very close to the results reported by SRDI (2001) for similar soils in AEZ 14. Soil pH depends on the type of basic rock or parent material, and rainfall is also a major factor contributing to increased soil acidity. The use of nitrogenous fertilizers without the application of lime also contributes to soil acidification. These factors may explain the acidic nature of the soils in the present study.

The EC values ranged from 0.11 to 0.74 dS m-1, indicating that the soils are non-saline in nature (BARC, 2012). No significant differences were observed among the soils of the AEZ or within the same soil series. The exchangeable potassium content ranged from 0.008 to 0.025 cmol kg-^{1}, which is considered low in most of the soils.

Table 4. Semi-quantative estimation of minerals in the clay fraction (< 2μm) of the soils

Soil Series	% Mineral content*						
	Mc	St	Ch	Kt	Qr	Gt	Fd
Harta1	39	33	7	6	12	0	3
Satla2	53	26	5	4	10	0	2
Harta3	53	21	3	4	16	0	3
Satla4	40	28	6	9	12	0	5
Satla5	69	3	5	6	13	0	4
Harta6	49	24	6	8	9	0	4
Harta7	33	33	8	7	12	0	7
Harta8	31	45	3	5	11	0	5

*According to the methods of Moslehuddin and Egashira (1996) and Islam and Lotse (1986)
Abbreviation: Mc-Mica; St = Smectite; Ch = Chorite; Kt = Kaolinite; Qr = Quartz; Gt = Geothite; Fd = Feldspar.

Except for the Satla-4 soils, where it was at a medium level, the exchangeable Na in the soil samples was generally low. The exchangeable Ca content of soils varied from 30.15 to 2.49 cmol kg-^{1}. According to BARC (2012), the exchangeable Ca status of the soils is generally medium to very high, ranging from 0.056 to 0.921 cmol kg-^{1}. In the present study, the highest exchangeable Ca was observed in Harta-3 series, and the lowest in Harta-8 series. The results are closely aligned with those reported by SRDI (2001) for the same region.The exchangeable Mg ranged from 5.72 to 2.50 cmol kg-^{1}. A high amount of Mg was present in the soils of Satla-2 series, while the lowest was noted for the Harta-8 series.

The mineralogical composition is the central theme of the present study. In AEZ 14 the result indicated that mica and smectite was the most predominant mineral in all the soil samples. The kaolinite and chlorite minerals were present in almost similar amount. Quartz and feldspar were also present in the studied soil samples in modest quantities. Moslehuddin and Egashira (1999) while preparing a tentative mineralogical map of Bangladesh, put the soils of this AEZ in mica-smectite* suite. This means mica and smectite were the major minerals with some kaolinite and chlorite also present in considerable amount. In this study, mica and kaolinite were the major minerals along with chlorite and kaolinite minerals. Thus the results of the present study partly support the mineralogical suite proposed by Moslehuddin and Egashira (1999). More study is required with samples from other areas of same AEZ.

5. Conclusions

The soils of Gopalganj-Khulna beels were mostly medium textured, slightly acidic to acidic and non-saline in nature. The mica, smectite, chlorite and kaolinite were found most dominant minerals in all the soil samples along with some quartz and feldspar present in the clay fraction. Same study is needed on the soils from other AEZs. The findings of the current study have significant implications for future research and policy decisions in terms of determining soil properties, nutrient storage and supplying capacity and other agronomic management for different crops.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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