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Characterization of sugar factory effluents from different factories of north coastal Andhra Pradesh, India and its effect on soil properties

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Abstract
Sugarcane is important sugar crop which is accounting for approximately 80 percent of world sugar production. Sugarcane is one of the important agro industrial crops of commercial importance grown in North Coastal Andhra Pradesh, India. During processing of cane, sugar mills will discharge huge amounts of wastewater as large quantities of water is utilized in sugar mills. However, water resources are limited and a wide gap exists between available water supply and the amount of water required for intensive cropping, appropriate use of industrial effluents may be helpful in meeting a part of the increased water demand. No systematic study has been carried out so far to assess the relative heavy metals availability in soils irrigated with effluent waters. Therefore, a study was undertaken to survey both surface and subsurface soils irrigated with effluent waters for availability of heavy metals and also to assess the contents of the pollutant elements in sugar industrial effluents at the point of source. Survey of effluents and irrigation waters for their quality (heavy metal, RSC, SAR, pH and EC) with special reference to sugarcane cultivation in different factory zones of North Coastal Zone was carried out during 2011-12 and 2012-13.Effluents samples were collected from all the five existing sugar factory areas of North Coastal Andhra Pradesh *viz.*, M/s Thummapala Cooperative sugar factory, Anakapalle, M/s Etikoppaka Cooperative sugar factory, Darlapudi and M/s Govada Cooperative sugar factory, Chodavaram of Visakhaptanm district; M/s GMR Sugar factory, Sankili of Srikakulam district and M/s NCS sugars, Bobbili of Vizianagaram district. Results revealed that all sugar factory effluents are highly acidic with the pH values varying from 4.32 (M/s Govada Cooperative sugar factory, Chodavaram) to 5.50 (M/s Etikoppaka Cooperative sugar factory, Darlapudi). However after effluent treatment, the pH values in all the factory areas were reached to safer limits. Concentrations of magnesium, calcium, sodium and sodium absorption ratios are within the limits in all the factory effluents. Heavy metals *viz.*, cadmium and lead also not recorded in factory effluents, whereas cobalt, nickel and chromium are found in traces. Hence, effluents from all the sugar factories can be used safely for irrigation with respect to concentration of heavy metals in the sugar factory effluents. Data on soil analysis results revealed that, effluent irrigated soils are neutral in reaction with non-saline in conductivity. Mean organic carbon content pertaining to all the five factory soils was medium in range. Hence, it is found safe to irrigate soils with treated sugar factory effluents as of soil physico-chemical and chemical properties are at permissible limits and for sugarcane cultivation.

Keywords: Characterization, sugar factory, soil properties

Introduction
Water is considered as the basic requirement of life on this earth. For meeting ever increasing demand of irrigation water, judicious utilization of water resources is crucial to agricultural production. The quality of water used for irrigation is essential for the crop yield, quality of crops, maintenance of soil productivity and environment protection. However, water resources are limited and a wide gap exists between available water supply and the amount of water required for intensive cropping, appropriate use of industrial effluents may be helpful in meeting a part of the increased water demand.

Sugarcane (*Saccharum officinarum* L.) is a vital as well as profitable crop of the tropical and subtropical countries. Sugarcane is important sugar producing crop accounting for approximately 80 percent of the world's sugar production. (Islam *et al.*, 2018; Sharma and Chandra, 2018) [4, 8]. It is one of the commercial crops having agro industrial importance being cultivated in North Coastal Andhra Pradesh, India. During processing of cane, sugar mills will discharge huge amounts of wastewater as large quantities of water is utilized in sugar mills. The effluent from sugar mill is mixed normally with different chemicals used during processing [Hsieh *et al*, 1995 and Verma *et al*, 1998]. As sugarcane contain about 70-80 percent water in cane itself, large amount of wastewater is generated in the industry during crushing and processing. [Sanjay *et al*, 2005 and Trivedy *et al*, 2017]. It is estimated that about 0.73 m^3 (730L) of water will be generated from every single ton of sugarcane being processed (Mohammad *et al*, 2019) [6]. The effluents from sugar industries are either released to channels or disposed off on land is of great concern with respect to soil-plant-water pollution on the cultivated fields. Since, these effluents contain high amount of trace elements and other pollutant heavy metals, when wastewater from industries is used for irrigation purpose, these non-essential heavy metals are taken up by plants and become the part of food chain (Ahmad *et al.*, 2018a) [1]. The unwise use of industrial waste water for irrigation continuously has elevated levels of available heavy metals in the cultivated layers of the soil (Schirado *et al*, 1996, Totawat, 1991). The effluents contains variable amounts of trace metals with high suspended solids, therefore necessary caution has to be exercised in its use. Effluent waters also contain appreciable amounts of major essential plant nutrients; hence the fertility level of soil is expected to improve considerably by application of these effluent waters after appropriate treatment. The nutrient content of these effluents and increasing scarcity of water have been made them attractive source of both. No systematic study has been carried out for the assessment of relative availability of heavy metals in soils irrigated with effluent waters. Therefore a study was undertaken to survey both surface and subsurface soils irrigated with effluent waters for relative availability of heavy metals and also to assess the contents of these pollutant elements in sugar industrial effluents at the point of source.

Methods and Materials

Survey of effluents and irrigation waters for their quality (heavy metal, RSC, SAR, pH and EC) with special reference to sugarcane cultivation in different factory zones of North Coastal Zone was carried out during 2011-12 and 2012-13.Effluents samples were collected from all the five existing sugar factory areas of North Coastal Andhra Pradesh *viz*., M/s Thummapala Cooperative sugar factory, Anakapalle, M/s Etikoppaka Cooperative sugar factory, Darlapudi and M/s Govada Cooperative sugar factory, Chodavaram of Visakhaptanm district; M/s GMR Sugar factory, Sankili of Srikakulam district and M/s NCS sugars, Bobbili of Vizianagaram district. In the said five factories, the untreated factory effluents were brought through drainage channels to the primary treatment tank, where the solid portion and liquid effluents were separated. Then the effluent waters were treated with lime and alum for pH maintenance before diverted to secondary treatment tank and effluents were treated aerobically and discharged in to the out fall canal. This treated effluent water was made available to the farmers for irrigation to the surrounding fields. Two liters capacity plastic bottles were used for collecting samples of effluents and irrigation water samples and the samples were collected in triplicate from selected sites. The effluent waters before and after treatment were collected and analyzed for their quality parameters i.e pH, EC, SAR, Mg/Ca ratio, RSC, TDS and trace metals by using standard methods as described by Tandon (1973) [9].

Soil Sampling

Soil samples were also collected from the fields irrigated with sugar mill effluents (SME). Collected the soil samples from four different sites where sugarcane crop was irrigated with effluent water. Collected surface soil samples at 0-30 cm depth in clean polythene bags. 2-3 kg of each soil sample was packed and transported, processed and analyzed for soil physicochemical and chemical properties at the soil laboratory (Jackson, 1967) [5].

Results and Discussion

Characterization of sugarcane industrial effluents

Results revealed that all sugar factory effluents are highly acidic in nature with pH varying from 4.32 (M/s Govada Cooperative sugar factory, Chodavaram) to 5.50 (M/s Etikoppaka Cooperative sugar factory, Darlapudi)(Table1). However after effluent treatment, the pH values in all the factory areas were reached to safer limits. Whereas, sugar factory effluents from all factories are non-saline with electrical conductivity ranged between 1.01 (M/s Etikoppaka Cooperative sugar factory, Darlapudi) to 2.64 dSm^{-1} (M/s GMR Sugar factory, Sankili) before treatment and reached to much safer limits for sugarcane crop irrigation. Regarding total dissolved solids (TDS), Chodavaram factory effluents showed highest value of 2320 ppm and lowest TDS value of 1260 ppm was recorded in Etikoppaka sugar factory effluents. After treatment the TDS values were reduced to 1321, 1306, 1132, 1031 and 1010 ppm in Thummapala, Sankili, Bobbili, Etikoppaka and Govada Cooperative sugar factory areas, respectively and the TDS values of all sugar factory effluents were above the prescribed limits even after treatment for effluents and to be discharged for irrigation.

Chlorides in effluents before treatment varied from 4.5 meq/lt(M/s GMR Sugar factory, Sankili) to 7.0 meq/lt (M/s Thummapala Cooperative sugar factory, Anakapalle) (Table2) and bicarbonates varied from 21.5 meq/lt (M/s Thummapala Cooperative sugar factory, Anakapalle) to 25.5 meq/lt (M/s NCS sugars, Bobbili) and upon treatment they were further reduced, however both chlorides and bicarbonates are found in the safer limits for irrigation.Maximum Residual Sodium Carbonate (RSC) of 4.8 was recorded in Chodavaram Sugar factory effluents and minimum RSC of 0.8 was recorded in Etikoppaka Sugar factory effluents before treatment (Table3). According to the critical limit for RSC (1.25), except Govada Cooperative sugar factory effluents, all other four sugar factory effluents are found safer in terms of RSC both before and after treatment. Whereas, M/s Govada Cooperative sugar factory effluents are not found safe for irrigation even after treatment. Concentrations of calcium, magnesium, sodium and sodium absorption ratios are within the limits in all the factory effluents. Heavy metals *viz*., cadmium and lead also not recorded in factory effluents, whereas cobalt, nickel and chromium are in traces (Table4). Therefore, effluents from all the sugar factories can be used safely for irrigation with respect to concentration of heavy metals.

Quality parameters of sugar factory effluents.

Table 1: pH, EC (dS m^{-1}) and total dissolved solids (mg/lt) in sugar factory effluents

Sugar factory area	pH		EC (dS m-1)		TDS (mg/lt)	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
M/s Thummapala Cooperative sugar factory, Anakapalle	5.50	7.11	1.30	1.05	1460	1321
M/s Etikoppaka Cooperative sugar factory, Darlapudi	4.32	7.20	1.01	0.83	1160	1031
M/s Govada Cooperative sugar factory, Chodavaram	4.80	6.05	1.85	0.79	2320	1010
M/s GMR Sugar factory, Sankili	5.45	7.08	2.45	1.10	1430	1306
M/s NCS sugars, Bobbili	4.80	7.18	2.64	0.93	1650	1132

Table 2: Existence of Chlorides, Carbonates and Bicarbonates in sugar factory effluents

Sugar factory area	Cl^- (meq/lt)		CO_3^{--} (meq/lt)		HCO_3^- (meq/lt)	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Anakapalle	7.0	5.0	0	0	21.5	18.8
Etikoppaka	6.2	5.0	0	0	23.8	17.5
Chodavaram	7.0	4.0	0	0	24.8	17.6
Sankili	4.5	4.2	0	0	22.6	19.4
Bobbili	5.2	5.0	0	0	25.5	17.5

Table 3: Existence of salts, RSC and SAR in sugar factory effluents

Sugar factory area	Ca^{2+} (meq/lt)		Mg^{2+} (meq/lt)		Na^+ (meq/lt)		Mg/Ca ratio		RSC		SAR	
	Before treat-ment	After treat-ment	Before treat-ment	After treat-ment	Before treat-ment	After treat-ment	Before treat-ment	After treat-ment	Before treat-ment	After treat-ment	Before treat-ment	After treat-ment
Anakapalle	6	6	14	12	5.56	4.72	2.3	2.0	1.5	0.8	1.24	1.11
Etikoppaka	8	6	15	11	5.75	3.92	1.88	1.83	0.8	0.5	1.22	0.96
Chodavaram	8	8	12	7	4.05	2.81	1.5	0.88	4.8	2.6	0.91	0.73
Sankili	8	7	13.5	8	6.5	4.03	1.69	0.94	1.1	0.80	2.60	1.04
Bobbili	9	6	15	12	2.5	3.92	1.65	1.83	1.5	0.5	1.80	0.96

Table 4: Existence of Heavy metals in sugar factory effluents

Sugar factory area	Pb (ppm)		Cd (ppm)		Co (ppm)		Ni (ppm)		Cr (ppm)	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Anakapalle	0	0	0	0	0.06	0	Traces	0	0.066	0.061
Etikoppaka	0	0	0	0	0.08	0.03	0.51	0	0.35	0.32
Chodavaram	0	0	0	0	0.15	0.11	0.15	0.11	0.72	0.69
Sankili	0	0	0	0	0.06	0	0.06	0	0.07	0.06
Bobbili	0	0	0	0	0.06	0	0.51	0	0.42	0.31

Physicochemical and chemical properties of soils irrigated with effluents

Table 5: Physicochemical properties of soils irrigated with effluents.

Sugar factory area	pH		EC (dS m^{-1})		OC (%)	
	Range	Mean	Range	Mean	Range	Mean
Anakapalle	6.67-6.92	6.85	0.224-0.310	0.294	0.24-0.62	0.53
Etikoppaka	7.05-7.55	7.34	0.523-0.661	0.587	0.43-0.76	0.61
Chodavaram	6.54-7.01	6.74	0.305-0.574	0.514	0.48-0.67	0.55
Sankili	6.2-8.3	7.4	0.226-0.654	0.446	0.39-0.66	0.57
Bobbili	6.7-8.1	7.6	0.199-0.561	0.347	0.58-0.72	0.61

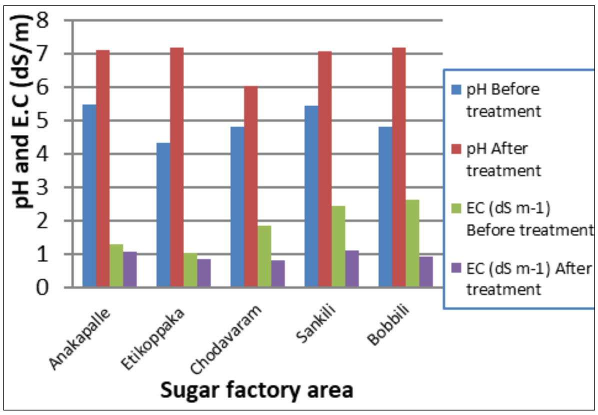

Fig 1: pH and EC in sugar factory effluents

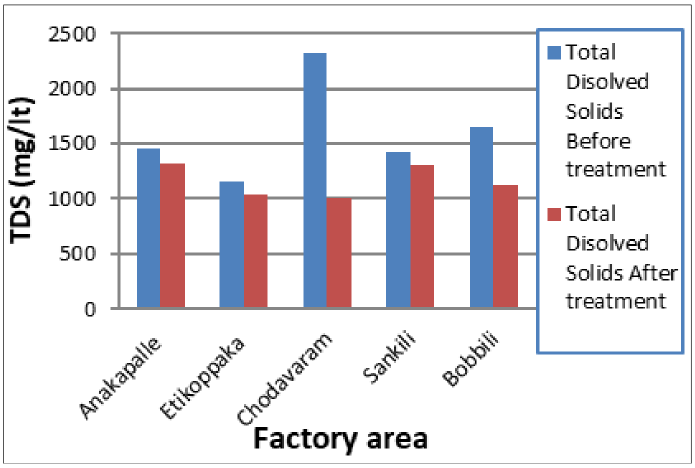

Fig 2: Shows total dissolved solids

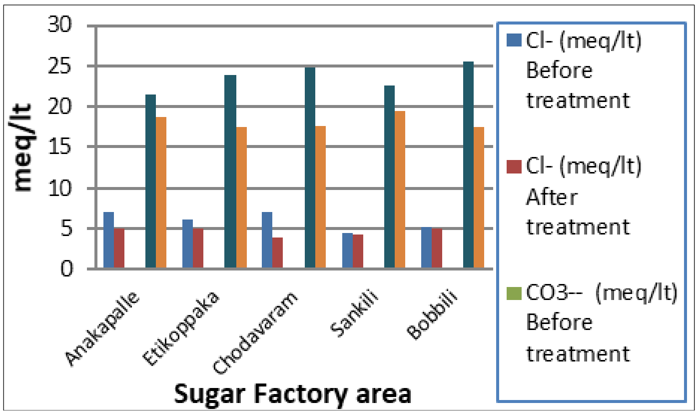

Fig 3: Existence of chlorides, Carbonates and Bicarbonates in sugar factory effluents

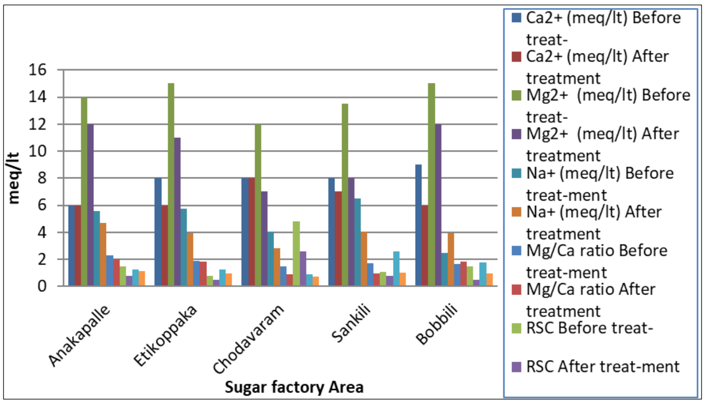

Fig 4: Shows existence of salts, RSC and SAR in sugar factory effluents

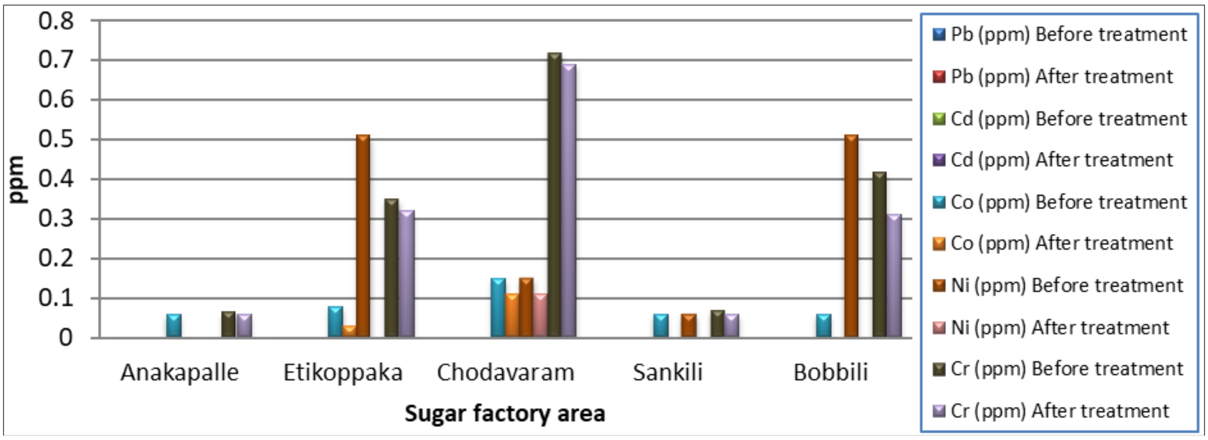

Fig 5: Existence of heavy metals in sugar factory effluents

Table 6: Chemical properties of soils irrigated with effluents

Sugar factory area	Ca^{2+} (Cmol kg^{-1})		Mg^{2+} (Cmol kg^{-1})		Na^{+} (Cmol kg^{-1})		K^{+} (Cmol kg^{-1})	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Anakapalle	22-34	27	7-11	10	4.52-5.40	5.15	1.5-4.5	1.95
Etikoppaka	35-40	37	11-14	12	1.10-4.20	3.39	1.65-5.2	3.4
Chodavaram	25-35	29	7-10	9	2.25-5.15	3.04	1.45-6.2	2.12
Sankili	22-37	29	6-11	9	1.22-4.38	3.82	1.56-5.0	3.21
Bobbili	20-31	25	7-12	9	4.40-5.52	5.04	1.2-4.0	2.12

Physicochemical and chemical properties of soils irrigated with effluents

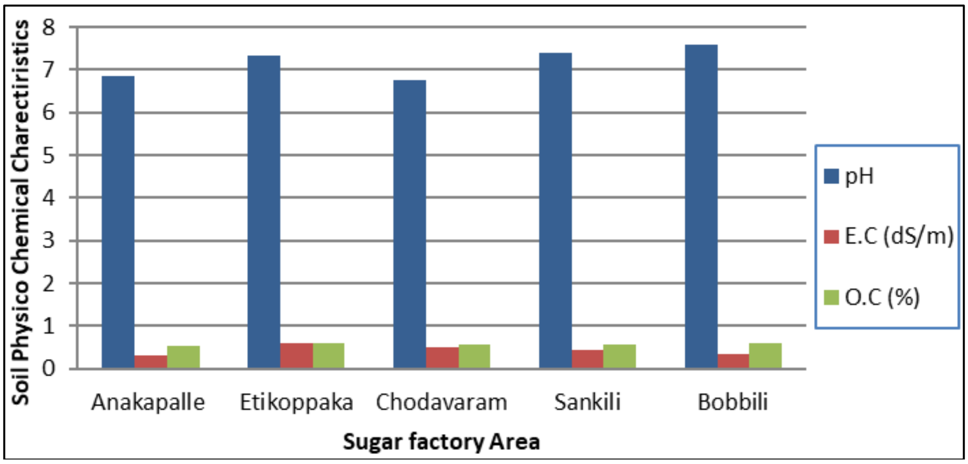

Fig 6: Physico chemical properties of soils irrigated with effluents

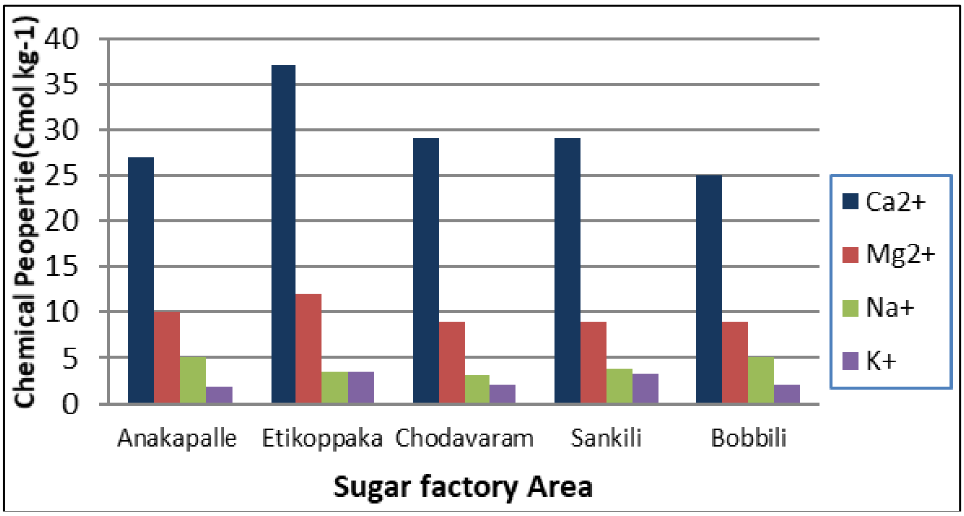

Fig 7: Shows Chemical properties of soils irrigated with effluents

Effect of Sugar factory effluents on soil properties

Data on soil analysis results revealed that, effluent irrigated soils are neutral in reaction with non-saline in conductivity. The organic carbon content ranged between 0.24 to 0.62 percent, 0.43 to 0.76 percent, 0.48 to 0.67 percent, 0.39-0.66 percent and 0.58-0.72 percent with mean values of 0.53, 0.61, 0.55, 0.57 and 0.62 percent in Thummapala, Etikoppaka, Chodavaram, Sankili and Bobbili sugar factory areas, respectively (Table5). Mean organic carbon content from all the five factory soils was medium in range and highest mean organic carbon of 0.62 percent was recorded in soils collected from Bobbili sugar factory area.

Among exchangeable bases in soils irrigated with effluents, calcium was found to be the dominant cation followed by magnesium>sodium>potassium (Table6). Calcium (Ca) and magnesium (Mg) are considered as secondary macronutrients because they are less common yield limiting nutrients than the macronutrients (N, P, and K), and they are required in relatively large amounts by crops. The major processes in Ca and Mg cycling are plant uptake, exchange, precipitation, weathering, and leaching. Calcium is usually the dominant basic cation in soil cation exchange reactions, accounting for base saturation of more than 70 percent. Base saturation represents the percentage of the cation exchange capacity (CEC) occupied by basic cations (Ca, Mg, K, and Na), and increases with increasing soil pH. Hence, it is safe to irrigate soils with treated sugar factory effluents as physico-chemical and chemical properties of soils are at permissible limits and for sugarcane cultivation.

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