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RESEARCH ARTICLE

Characteristics of Sago Processing Wastewater Effluents released from different Sago Factories in Salem and Namakkal District of Tamil Nadu, India

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ABSTRACT

A study was undertaken to determine the physico-chemical characteristics of sago processing wastewater (SWW) from various sago industries in Salem and Namakkal districts of Tamil Nadu. Besides, different SWW (raw wastewater, aerobic wastewater, treated wastewater and starch wastewater) from within the industry were evaluated. The results concluded that effluents from this region are whitish and greyish brown in color with majorly supra-colloidal or settable suspended solids with high TS, TSS, and TDS. The ammoniacal, nitrate, and nitrite nitrogen ranged from 2.7 to 6.5, 4.5 to 19.1, and 0.4 to 2.8 mg.L^{-1}. The total nitrogen content and phosphate level of SWW samples were ranged from 180- 650 mg.L^{-1} and 640-1096 mg.L^{-1}. The BOD and COD content of SWW from all the industries ranged from 2560 to 3200 mg.L^{-1} and 34000 to 76000 mg.L^{-1} indicates its high organic nature. SWW effluents are acidic in nature (pH 4.3-5.2). The free cyanide (CN) content was ranged from 1.2 to 5.2 mg.L^{-1}. The treated wastewater had neutral pH (pH - 6.2), and had a reduced level of EC, starch content, TSS, COD and BOD.

Keywords: *Sago wastewater; Organic load; Treatment; Characteristics; Pollutants*

INTRODUCTION

Cassava (*Manihot esculenta*), a perennial root shrub belonging to the Euphorbiaceae family, has a starch content of 90 per cent (dry weight). It is a cheap source of nutritional carbohydrate energy (720-1012 kJ. day^{-1}) and ranks fourth after rice, sugarcane, maize, and stands fifth amid the starch crops in global production. Many starch factories based on cassava are located in tropical countries. Cassava is grown over an area of about 3 lakh hectares, with the tubers production rate of 58-60 lakhs tonnes. In Tamil Nadu, it is cultivated as an irrigated crop around an area of 82,000 hectares with 800 processing units.

During the extraction of the starch from tapioca tuber, about 20,000 to 30,000 L of water is required per ton of sago, eventually produced the same quantity of wastewater, with high chemical oxygen demand (COD) up to 25 g L^{-1} (Sen and Suttar, 2012), biodegradable starch (4-7 g. L^{-1}) and cyanide (5 mg. L^{-1}). Cyanide is extremely toxic, and it has a significant impact even at very low concentrations (1-2 mM) on many species (Potivichayanon *et al.*, 2020). The untreated effluents released from the sago industries affect the soil health, plants, animals, natural ecosystems, and human beings (Ruban *et al.*, 2013). The fermentation of residues can lead to the production of CO_2, acetic, and lactic acids, which add to intense odors (Cumbana *et al.*, 2007); it leads to serious environmental pollution.

Therefore, a considerable effort is needed to identify economic methods to reduce this pollution load. First of all, clear knowledge of the quality, quantity, and temporal changes in the composition of the effluent is needed for the successful treatment of wastewater. Physicochemical characterization is essential in order to finely identify the characteristics of a treatment method. Additionally, certain physico-chemical characteristics present a preliminary evaluation of the quality and degree of pollution of wastewater. The objective of the present study is, therefore the characterization and quantification of the organic contaminants (BOD, COD, TSS, nitrate, phosphate, cyanide, *etc*.,) of the sago processing wastewater.

MATERIAL AND METHODS

Study Area

Salem and Namakkal districts in Tamil Nadu are the tapioca processing clusters in India where large-scale production and tapioca processing is carried out. Nearly 34,000 acres of land is under tapioca

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cultivation and popularly called for the land of sago. The present study was carried out in Salem and Namakkal sago cluster areas. Site selection is based on the intensity of the small-scale manufactures in producing sago and wastewater disposal locations directly to the environment.

Collection of sago processing wastewaters from different locations

The sago processing wastewater (SWW) was collected in the airtight container from different sago industries located at the Salem and Namakkal districts of Tamil Nadu, India. The industry name, area, and geographical location are presented in Table 1 and Figure 1a. The different SWW such as raw wastewater, aerobic wastewater, treated wastewater, and starch wastewater were collected from different unit operation within the industry (TA Perumal starch industry) Figure 1b. The collected wastewaters were immediately stored at 4 °C until used for further experiments and analysis.

Physico-chemical property analysis

The physicochemical parameters (pH, EC, TDS, TS, salinity, total soluble starch, COD, and BOD) of SWW samples collected from various sago industries and different unit operations within the industry were analyzed as per the standard method of examining water and wastewater analysis (APHA, 2005). Macronutrients such as nitrogen (ammoniacal and nitrated) and phosphorous in wastewater were estimated in accordance with the supplier's protocol by the probe photometer kits (Palintest 7500 Photometer, USA).

Cyanide estimation

The cyanide content was calculated by modifying the picric acid method (Fisher and Brown, 1952). A linear calibration curve was obtained with the standard cyanide solutions as follows: aliquots (0.05 mL) of cyanide solutions (after centrifugation at 15,000 g for 10 min at 4 °C) were added to 0.1 mL aliquots of a solution containing 0.5% (w/v) picric acid and 0.25 M Na_2CO_3. The resulting solution was put in a boiling water bath for 5 min, diluted to 1 mL with 0.85 mL of distilled water, and cooled for 30 min in tap water. At 520 nm, the absorbance was read against a blank of distilled water and picric acid reagent along with samples.

Statistical analysis

All experiments were performed in triplicate, and the average values with standard deviation were considered. Statistically significant differences between the physico-chemical properties between the industries were examined using one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) at 5% significance level.

RESULTS AND DISCUSSION

Physico-chemical characteristics of SWW from various sago industries

The physico-chemical characteristics of SWW from various industries are presented in Table 2. From the results, it was known that every industry had released its unique characteristic wastewater that depends on processing steps and raw materials.

Table 1. Industry name, geographical coordinates and area of the SWW collection sites used in the present study

Google map code	Name of industry	Geographical coordinates of sampling site		Area detail
		Latitude	Longitude	
A	SreeSelliamman sago factory	11.50 N	78.10 E	Thatchankadu, Alavaipatti, Nammakal, Tamil Nadu-637505
B	TA Perumal starch industries	11.65 N	78.11 E	Ezhil Nagar, Sivathapuram, Kanthampatty, Salem, Tamil Nadu-636005
C	Sri Senthil Andhavar sago factory	11.59 N	78.61 E	Eachampatti road, Attur taluk, Salem, Tamil Nadu-636141
D	S.R.T. Sago factory	11.55 N	78.63 E	Attur - Rasipuram - Erode Rd, Tamil Nadu - 636108

During the sago extraction process, tapioca roots are washed, debarked, rasped before milling or pulping process. The starch in the slurry is removed in these processes and left to be resettled, than compacted and agglomerated (Patle and Lal, 2008). During the entire production process, a large amount of water (20 litres of wastewater per kg of sago starch production) would be discharged as sago wastewater effluents.

The color of the SWW effluent samples observed in the present study was greyish to dark brown with whitish settlements due to the fermentation of remaining starch in the SWW. The changes of color are most probably due to the degradation of organic content in the effluents reacted to the microbial activities and anaerobic conditions (*Tchobanoglous et al.,* 2014). SWW temperature ranges from 26.1- 28.0°C; this is the optimum temperature for microbial growth. The pH of SWW from all the four factories was highly acidic ranged from 4.3 to 5.4 due to the release of hydrogen cyanide (HCN) from cassava tubers and the addition of sulphuric acid during the extraction process.

Table 2. Physico-chemical characteristics of SWW collected from different sago industries.

Properties	Sago Industries			
	A*	B	C	D
Color	Greyish	Greyish	Brown	Dull white
Odor	Pungent	Pungent	Pungent	Pungent
PH	4.7 (± 0.1) [b]	4.3(±0.0) [c]	4.3 (± 0.0)[c]	5.4 (±0.0) [a]
EC (dSm^{-1})	6.2 (± 0.1) [a]	3.3(±0.1) [b]	6.2 (±0.0)[a]	3.7 (±0.0) [b]
Salinity (mg. L^{-1})	4656.7 (±80.1) [a]	2460.0`(± 0.123) [b]	4533.3 (±33.3)[b]	4100.0 (±100.0) [b]
Temperature (C)	24.9 (±0.3) [a]	26.9(±0.3)[a]	24.8 (±0.3)[a]	24.7 (±0.2)[a]
Ammonium N_2 (mg. L^{-1})	5.2 (±0.0) [a]	ND	2.7 (±0.0)[b]	6.5 (± 1.1)[a]
Nitrate N_2 (mg. L^{-1})	4.5 (±0.0)[c]	ND	19.1 (±0.9)[a]	7.9 (± 0.2)[b]
Nitrite N_2 (mg. L^{-1})	0.4 (±0.0)[c]	ND	2.8 (±0.6)[a]	1.7 (±0.0)[b]
Phosphate (mg. L^{-1})	1096.0 (±58.4)[a]	128.3 (±31.1)[c]	1056.7 (±37.1)[a]	640.0 (±17.3)[b]
Total N_2 (mg. L^{-1})	650.0 (±23.1)[a]	180.0 (±34.9)[c]	436.7 (±12.0)[b]	383.3 (±14.5)[b]
TDS (mg. L^{-1})	4053.3 (±61.7)[a]	2311.9 (±12.1)[b]	4073.3 (± 6.7)[a]	2423.3 (±3.3)[b]
TSS (mg. L^{-1})	310.0 (±37.9)[d]	2420.8 (±234.0)[c]	6666.7 (± 833.3)[a]	4166.7 (±833.3)[b]
TS (mg. L^{-1})	5066.7 (±159.0)[b]	5921.0 (± 54.1)[b]	6900.0 (±100.0)[a]	2316.7 (±447.5)[c]
DO (mg. L^{-1})	8106.7 (±53.3)[a]	6200.9 (± 12.2)[b]	7840.0 (± 576.9)[a]	8213.3 (±232.5)[a]
BOD (mg. L^{-1})	2613.3 (±106.7)[a]	4650.0 (± 67.1)[a]	2560.0 (± 461.9)[a]	3200.0 (±160.0)[a]
COD (mg. L^{-1})	34000.0 (±2000.0)[b]	11625.0 (±256.1)[c]	76000.0(± 6928.2)[a]	74666.7(±8110.4)[a]
Soluble starch (mg.L^{-1})	4820.0 (±390.0)[c]	3233.0 (±0.7)[c]	6100.0 (± 0.8)[b]	12930.0(±0.1)[a]

Values represent mean (±standard error) (n=3) and values followed by the same letter in each column are not significantly different from each other as determined by DMRT ($p \leq 0.05$).

ND - Not determined, EC - Electrical Conductivity, dSm-1, DeciSiemens per metre. TDS – Total dissolved solids, TSS - Total suspended solids, TS - Total solids, DO – Dissolved oxygen, BOD - Biological oxygen demand, COD - chemical oxygen demand.

* Adopted from published data Kiruthika *et al.*, 2020

The entire process emitting obnoxious awfull smell thus cause pollution and deteriorating the environment quality, globally (Ibrahim *et al.*, 2006 ; Yunus *et al.*, 2014). The EC and (3.3 - 6.2 dSm^{-1}) and salinity of SWW (2460.0- 4656.7 mg. L^{-1}) were varied, highest was recorded in the industry A and C.

Table 3. Physiochemical characteristics of different types of SWW collected from different unit operation within industry

Properties	Raw wastewater	Aerobic wastewater	Treated wastewater	Starch wastewater
Color	Dirty White	Dirty White	Dark Brown	Dirty White
Odour	Pungent	Light pungent	Light pungent	Pungent
pH	4.5	6.4	6.9	4.1
EC (dsm^{-1})	3.07	2.60	2.56	2.67
Salinity (mg. L^{-1})	2271	1962	1930	2024
Temperature (^{o}C)	26.9	26.1	26.4	26.7
Total N_2 (mg. L^{-1})	693.1	440.2	880.4	117.4
TSS (mg. L^{-1})	1272	1858	1414	1472
DO (mg. L^{-1})	6.4	6.4	7.2	6.4
BOD (mg. L^{-1})	4800	4000	3200	4800
COD (mg. L^{-1})	8800	6400	5600	7200
Soluble starch (mg. L^{-1})	3767	2348	1698	4067

EC - Electrical Conductivity, TSS - Total suspended solids, DO – Dissolved oxygen, BOD - Biological oxygen demand, COD - chemical oxygen demand.

The nutrients such as nitrogen (ammoniacal and nitrate) and phosphorus were sufficiently present in all industrial effluents to support microbial growth. The ammoniacal, nitrate, and nitrite nitrogen ranged from 2.7 to 6.5 mg. L^{-1}, 4.5 to 19.1 mg. L^{-1} and 0.4 to 2.8 mg. L^{-1}, respectively. The total nitrogen content of SWW samples was ranged from 180- 650 mg. L^{-1}. The phosphate level of SWW was very high (640-1096 mg. L^{-1}) in all the industries compared to its nitrogen content.

Due to its diverse densities of substances, i.e., the settable, suspended, and floatable solids material, the wastewater effluent samples were easily settled into three layers of notifiable upper,

Series of starch settling tank

Wastewater storage tank and sample collection

Figure 1a. Observation of sago processing and collection of different kinds of waste water generated within the industry

middle, and lower layers. In general, the TS, TSS, and TDS content of SWW samples in the present study were high due to the presence of rich carbohydrates, fibres and dense suspended solids, unextracted starch, cellulose (fibrous residue from pith), nitrogenous compounds, cyano glucosides and insoluble fibres.

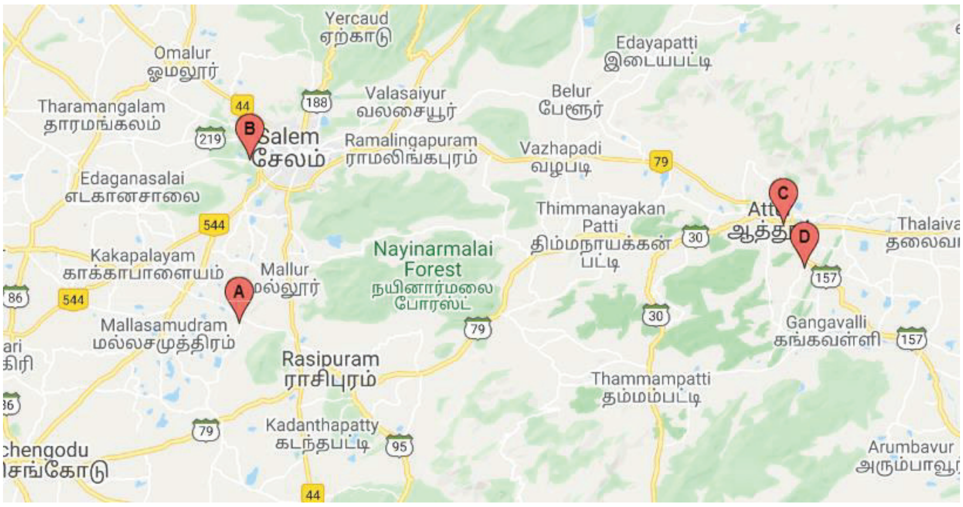

Figure 1b. Geographical location of the industries in Google map

The BOD and COD content of SWW from all the industries ranged from 2560 to 3200 mg. L^{-1} and 34000 to 76000 mg. L^{-1} indicates the high organic nature of SWW. The content of BOD and COD has exceeded the quality standard recommended by the central pollution control board (100 and 300 mg. L^{-1}).

Physico-chemical characteristics of SWW collected from different unit operation within the industry

Different sago industries released their unique SWW vary in their properties. Similarly, within the industry, every unit operation has an impact on the characteristics of wastewater. To study their impact in detail, four kinds of wastewaters were collected within the industry itself. Raw wastewater, was released entirely after the starch extraction process into the wastewater storage tank 2. Aerobic water, was collected from the initial wastewater aerobic treatment system, 3. Treated water, collected from final anaerobic treatment system 4. Starch water is directly collected from the starch settling tank. The results are presented in Table 3. When comparing their properties, the treated wastewater had neutral pH (pH - 6.2), and had a reduced level of EC, starch content, TSS, COD. The soluble starch content in the treated wastewater was low compared to other wastewater due to the microbial fermentation process. Surprisingly the total nitrogen content of treated water was high compared to other wastewater may be due to the release of both organic and mineral nitrogen during the anaerobic treatment process.

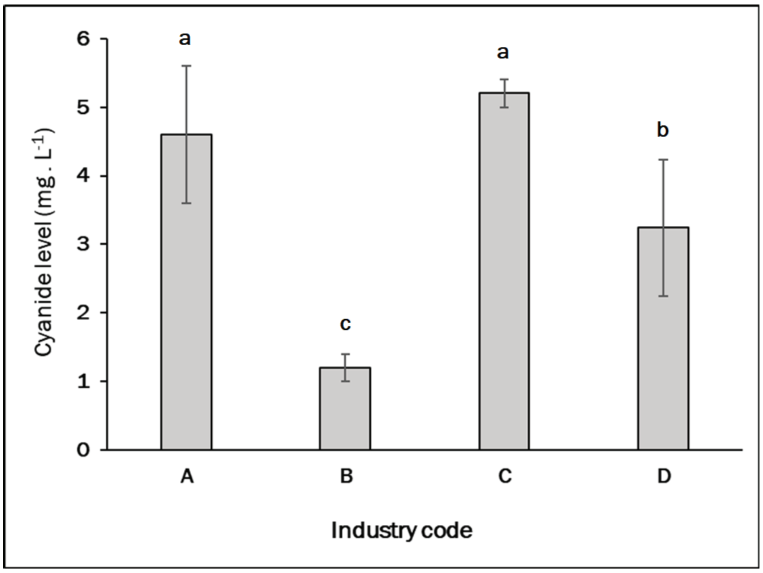

Figure 2. Cyanide level observed in different sago industries

Cyanide toxicity level

The potential cyanide content in tapioca varies with the variety, the environmental conditions, and the time of harvest. During the starch extraction process, cyanide bounded in tapioca roots was hydrolyzed with hydrogen cyanide released into the wastewater by linamarase in the tapioca tissue (Arotupin 2007; Sujatha Kandasamy *et al*., 2015). The level of release depends on the concentration of the enzyme. In the present study, the significant ($p < 0.05$) difference observed in the cyanide level, the free cyanide (CN) content was ranged from 1.2 to 5.2 mg. L^{-1} (Figure 2). In other studies, the cyanide concentration in SWW has been reported to range between 10.4 and 274 mg.L^{-1} depending on the cyanoglycoside content of the tapioca varieties (Siller and Winter, 1998; Balagopalan and Rajalekshmy, 1998).

CONCLUSION

The present study shows a detailed physico-chemical variations of sago wastewater from the different scaled industrial units. The various parameters of SWW were possessed higher values than the levels stipulated by the Tamil Nadu Pollution Control Board. The treated wastewater had neutral pH (pH - 6.2) and had a reduced level of EC, starch content, TSS, COD and BOD. Hence, necessary action should be taken to treat the wastewater effectively in order to reduce the environmental threats related with wastewater discharge into the receiving ecosystem.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

Authors should ensure that they have written and submit only entirely original works.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There was no conflict of interest in the publication of this content

Data availability

All the data of this manuscript are included in the MS.

Author contributions

Research grant, Idea conceptualization- US; Experiments- SN, KT, AS; Guidance- US; Writing-original draft- SN, KT; Writing- reviewing &editing –US.

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