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An approach to improve sustainability: performance of *Strychnos potatorum* seed as a natural coagulant in water treatment at tourist sites

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Abstract
Water is obviously an essential need for all living beings. The most important aspect is water quality for drinking purposes. In January 2024, water samples from Courtallam and Karaiyar were collected in order to test the water quality. In the current work, an attempt has been made to study the physical, chemical and biological characteristics of collected water. The obtained data were analysed with BIS. Additionally, an approach has been made to study the efficacy of *Strychnos potatorum* seed (SPS), a natural coagulant, for purpose of treating water. According to BIS, before treatment with SPS, both the collected water samples have shown the physical and chemical qualities as potable, but not biologically which shows the Fecal coliform is uncountable in both samples. After treating with SPS, as a remedial measure, the Fecal coliform is countable (decreases) and physically potable but chemically not potable as the value of pH is below the minimum permissible limit and the value of NH_3 exceeds the maximum permissible limit. The study strongly recommends to constantly monitor the quality of drinking water in the region and also suggest the natural coagulant, for removal of bacteria and turbidity from water to protect the health of the people.

Keywords: *Strychnos potatorum*, coagulation, physical, chemical, biological

Introduction

Water is the most crucial need for every human being living on Earth. Safe drinking water is the primary need of all people. The world's surface is mainly covered by water, about 70%. Of these, 97% are sea wa-ter (non-potable), 2.5% are freshwater that humans may access, and only 0.5% is utilized as drinking water (potable) (Ahn et al., 2018). Growing population, rapid urbanization, industrialization, lack of environmental awareness and governance failures are leading to an increase in wastewater discharge. These are some factors that make water unfit for human consumption. As many industries consider water bodies as the best place to discharge their waste, the quality of the water in the rivers deteriorates and naturally the ecosystem is disturbed to a large extent. The quality of drinking water is one of the major factors affecting human health. However, in many countries, especially developing countries, the quality of drinking water is undesirable and poor drinking water quality has triggered many waterborne diseases (Taiwo et al., 2020). An important domestic water source of Southern Tamil Nadu is Chittar and Thami-

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rabarani. The Courtallam hills in Tenkasi District are the source of the Chittar. Thamirabarani or Porunai is a perennial river that originates from the Agastyarkoodam peak of Pothigai hills in the Western Ghats above Papanasam. Chittar from Courtallam and Thamirabarani from Karaiyar are the places of tourist attractions. Understanding water quality requires quantitative knowledge of physical, chemical and biological properties and comparing their quantities with standards. The quality of water depends on the concentration of various components in it. The concentration of the components depends on its origin and the way it flows. Various water treatment techniques like adsorption (Rajendran et al., 2022), membrane technology (Hoek et al., 2021), photocatalysis (Sarathi et al., 2022), electrochemical techniques (Sillanpaa and Shestakova, 2017) are used to remove contaminants from water. Each indivi-dual has benefits and realistic limitations. Although various technologies are used in the water treatment industry, recent studies have focused on the coagu-lation technology, especially natural coagulants. It is essential to explore the potential of natural coagulants for water purification due to safe and cost-effective. Medicinal plants as natural coagulants are a rich source of great economic value and are non-toxic throughout the world. Plants like *Moringa oleifera* (Taiwo et al., 2020; Garcia-Fayos et al., 2016; Pandey et al., 2020), *Citrullus lanatus* (Misau et al., 2015), *Azadirachta indica* (Pandey et al., 2020), *Strychnos potatorum* (Neelamkavil and Thoppil, 2015) as natural coagulants were used to remove various contaminants from water. Among those, *Strychnos potatorum* (clearing nut) is a medium-sized medicinally important forest tree found in India which belongs to Loganiaceae (Mallikharjuna et al., 2007). SPS, clearing nut, is used as an excellent adsorbent for the removal of dyes such as reactive orange, methylene blue, congo red from industrial wastewater (Kirupa Sankar, 2015; Senthamarai et al., 2013; Sethurajan et al., 2011). As the name of the plant suggests, ripe seeds of *Strychnos potatorum* have been used to clean muddy water since ancient times (Subbaramiah and Rao, 1937). It is one of the natural purifying agents that has been tested over the years to develop sustainable environmental technology. Recently, SPS extract exhibits remarkable performance in domestic wastewater treatment by eliminating turbidity and phosphate. Bioactive compounds in SPS such as alkaloids, anthraquinones, carbohydrates, cardiac glycosides, sterols and saponins have been identified which are responsible for coagulation activity. The important water quality parameters, physical and chemical properties have been elucidated but not biologically determined (Sheeba et al., 2023). Therefore, in this present work, SPS as a natural coagulant has been used to test the quality of water collected at tourist sites. Physico-chemical parameters like turbidity, TDS, EC, pH, TA, TH, Ca, Mg, Na, K, NH_3, NO_2, NO_3, Cl and SO_4 are examined. The novelty of the present work is to determine the biological characteristics (Fecal coliform) of the water.

Materials and Methods

Sample collection

Water samples were collected in 2-litre polyethylene bottles from the tourist places of Courtallam and Karaiyar (Table 1) (Fig. 1). Prior to sample collection, the bottles were washed with dilute acid, rinsed with distilled water and dried in an oven.

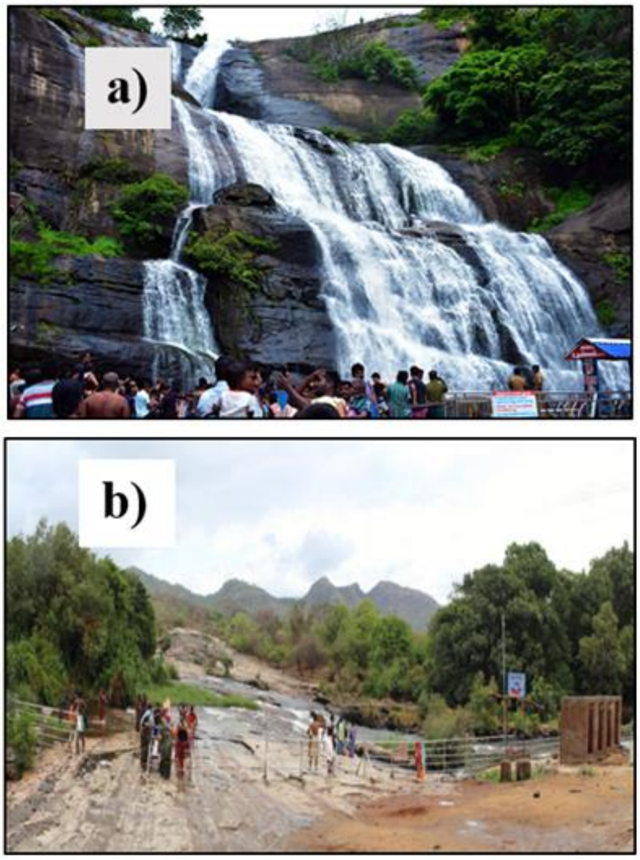

Figure 1. *Places of the sample collected* a) *Courtallam* b) *Karaiyar*

Preparation of coagulant

SPS (Fig. 2) were procured from the market and washed using distilled water to remove the surface impurities present in it. The material was dried in sunlight to remove the moisture. The dried materials

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S. No.	Sample	Water flow	Place	Source	District	Map
1.	S1	Chittar	Courtallam	Falls	Tenkasi	
2.	S2	Thamirab arani	Karaiyar	River	Tirunelveli	

Table 1
Sample collections

Figure 2. *Strychnos potatorum seed*

were finely powdered. This powder was utilized as a coagulating agent to test various water quality parameters (Sheeba et al., 2023).

Coagulation treatment

The jar test is a very commonly used experimental tool in the coagulation and flocculation process. Using a natural coagulant, a typical jar test apparatus was used to coagulate the collected water. The collected water samples were analyzed in the laboratory for various water qualities without addition of SPS powder (untreated water). Then, the collected water samples were treated with SPS powder for coagulation study. Firstly, the initial turbidity of the samples was noted prior to the addition of coagulant. To treat with coagulant, 500 mg of coagulant dosage was added to 500 mL water sample and stirred at a high speed of 150 rpm for 5 min. Then the mixing speed was reduced to 30 rpm for about 25 min. The supernatant was then collected without disturbing the settled particles (after 1 h). Turbidity is now observed and the sample is stored at 4°C for further water quality analysis (Sheeba et al., 2023).

Analytical methods

Physical characteristics such as turbidity were assessed using a Digital Nephelo-turbidity meter (Systronics, Model No. 132), an EC using EC meter (Systronics - MK 509), and pH by Digital pH meter (Scientific tech - ST 2001). The chemical parameters determined in this study such as Ca, Na, K by Flame Photometer (Systronics - Model: 130), TA by acid base titration, Mg using EDTA titrimetric method, Cl by Silver Nitrate Titration, NH_3, NO_2, NO_3 and SO_4 using colorimeter (Systronics Instruments - 113). The biological parameter (Fecal coliform) by Bacteriological Incubator (Hasthas Instruments) were assessed.

Characterization studies of natural coagulant

In this study, X-ray diffraction (XRD), Ultraviolet-visible (UV-Vis) spectrophotometry and Fourier transform infrared (FT-IR) spectrophotometry analyses were performed in order to characterize the natural coagulant, SPS powder. The XRD used is X-Pert Pro PANalytical, UV-Vis used is UH-5300 (HITACHI MODEL) and FT-IR used is Nicolet IS5R.

Results and Discussion

Water quality analysis

The concentration of physical, chemical and biological parameters in water before and after treatment was determined and compared with the Bureau of Indian Standards (BIS) (Table 2).

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Table 2. *Physical, Chemical and Biological Parameters of water*

S. No.	Parameters	In terms of	Acceptable limit	Permissible limit in the absence of alternate Source	S1		S2	
			BIS 10500:2012 [IS10500, 2012]		Before treated with coagulant	After treated with coagulant	Before treated with coagulant	After treated with coagulant
Physical Examination								
1.	Turbidity	NTU	1	5	1	0.71	1	0.65
2.	TDS	mg/L	500	2000	37	46	23	44
3.	EC	µS/cm	-	-	54	67	34	64
4.	pH		6.5-8.5	6.5-8.5	7.01	6.15	6.73	4.94
Chemical Examination								
5.	TA	mg/L	200	600	12	12	8	8
6.	TH	mg/L	200	600	11	17	5	13
7.	Ca	mg/L	75	200	1	4	1	3
8.	Mg	mg/L	30	100	1	2	1	1
9.	Na	mg/L	-	-	5	5	4	6
10.	K	mg/L	-	-	4	5	3	5
11.	NH_3	mg/L	0.5	0.5	0	2.71	0	1.97
12.	NO_2	mg/L	-	-	0	0.02	0	0.04
13.	NO_3	mg/L	45	45	2	6	1	6
14.	Cl	mg/L	250	1000	8	10	2	10
15.	SO_4	mg/L	200	400	5	5	2	3
Biological Examination								
16.	Fecal coliform per 100 ml	CFU	Nil/100ml	Nil/100ml	Uncountable	150	Uncountable	150

Physical Examination

Turbidity is the measure of clarity of a water body which refers to water transparency or clearness (Anderson, 2005) The water flow in both the districts ranges 1 NTU. After treatment with coagulant, the turbidity value was reduced to 0.71 NTU and 0.65 NTU. It shows the decrease in turbidity value using SPS powder as coagulant (Gaikwad and Munavalli, 2019). BIS permissible limit for turbidity is up to 5 NTU. As a result of turbidity, all water samples are safe within range. Total Dissolved Solids (TDS) of water includes the organic and inorganic matters (Rahmanian et al., 2015). Water with TDS greater than 500 mg/L is undesirable for drinking purposes. In the present study, the concentrations of TDS before and after treatment ranges from 23 to 46 mg/L. After treatment with coagulant, the effect is slightly increased. It might be due to added solutes in water. Electrical Conductivity (EC), also referred to as specific conductance, is the ability to conduct electricity which is related to the ionic content of the sample. According to WHO standards, the maximum permissible limit of this parameter is 400 µS/cm (Meride and Ayenew, 2016). There are no recommended values by BIS standards. The current investigation indicated that EC value varies between 34 and 67 µS/cm. All the tested samples for EC are safe within the BIS standards. On comparison with pre-treatment of SPS powder, the value of EC increases which may blossom in mineral flavour of water. Higher EC values lead to higher concentrations of ionic constituents in water. There are no direct human health effects associated with conductivity. pH of a solution is to determine whether the liquid is acid or alkaline. A sample is considered as acidic if the pH is less than 7.0. In the meantime, it is alkaline if the pH is above 7.0. The peak of pH may influence the palatability of the water. Beyond the mentioned aspects, pH values regulate the behavior of many other water quality parameters. The most frequently encountered range for drinking is 6.5-8.5. Before treating with coagulant, the pH is safe within the limit according to BIS standards. After treating with coagulant, the pH value falls below the minimum permissible limit that is due to Ammonia toxicity caused by the coagulant. Similar reports after treatment with SPS showed the decreasing pH values for drinking water (Anderson, 2005).

Chemical Examination

Total Alkalinity (TA) in natural water might be the result of bicarbonates that react in the soil through which water penetrates. However, the desirable limit by BIS for TA is 200 mg/L and the domestic use of

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water with an alkalinity lower than 100 mg/L is safe (Gaikwad and Munavalli, 2019). The obtained value of samples before and after treatment remains the same. In the present work, the obtained results showed that they were safe to drink. Water hardness is an important factor in determining the suitability of water for domestic use. Total Hardness (TH) is used to measure the concentration of total divalent ions in water. Analysis involves determining the hardness of Ca and Mg (the most common sources). The widespread presence of these metals in rock formations leads to the very significant hardness of water. The following is one of the arbitrary classifications of water in terms of hardness (Atwebembeire et al., 2018): Soft → up to 50 mg/L $CaCO_3$ - Moderately Soft → 51-100 mg/L $CaCO_3$ - Slightly Hard → 101-150 mg/L $CaCO_3$. Moderately Hard → 151-250 mg/L $CaCO_3$ - Hard → 251-350 mg/L $CaCO_3$ - Excessively Hard → above 350 mg/L $CaCO_3$.

The present work of TH before and after treatment showed a level of less than 50 mg/L. Inadequate intake of Ca and Mg can lead to poor health. Naturally soft water requires stabilization and corrosion reduction treatment prior to serving it to the public. Soft water may have aggressive properties towards the pipe material from which it is distributed. Water is generally conditioned or stabilized to avoid corrosion in the galvanised iron pipe. Often this involves adding alkalinity and/or corrosion-resistant substances. Depending on local circumstances, water providers and public health officials may want further alteration in the composition of drinking water in the light of global mineral nutrition. Calcium (Ca) is an essential mineral required for various physiological functions of the human body. An adequate intake of Ca is essential to normal growth and health (World Health Organization, 2009). High doses in public water supply are beneficial and Ca-rich waters (and therefore very hard) are very palatable. Ca is generally required at 75 to 200 mg/L in drinking water. In present work, Ca in untreated samples showed 1 mg/L. In SPS treated water the level of Ca increases around 4 mg/L. The results in treated and untreated samples showing relatively less variation of Ca which are safe within the BIS standards. Magnesium (Mg) is also an essential element for human growth and development (World Health Organization, 2009). Mg value in untreated water is found to be 1 mg/L. The value gets increased while treated with coagulant. The concentration of Mg in the treated sample might be due to deposits of minerals present in SPS powder. Mg concentration in untreated and treated samples is too less but is well within the permissible limit set by BIS. Sodium (Na) is an abundant component found everywhere in natural water. Na-rich water may cause alkalinity in the presence of bicarbonate ions. Na concentration observed in the present work is between 4 and 6 mg/L. According to BIS standards, there are no effects of toxicity on Na, all the samples are safe within the limits. Akalinity also depends on the amount of Potassium (K) salts. Determination of this salt is often carried out when evaluating nutrient input. No effects of toxicity. The value of tested samples before and after treatment with SPS ranged between 3 and 5 mg/L which are safe within the BIS standards. In the perspective of human health, the importance of free Ammonia (NH_3) is pointed out. In untreated samples, the value of NH_3 is found to be 0 mg/L. After treatment with coagulant, the level of NH_3 exceeds the maximum permissible limit (Packialakshmi et al., 2014). This might be due to the presence of nitro compounds present in SPS (Fig. 5).

The importance of nitrite (NO_2) primarily refers to hazardous wastewater pollutants. In present work, the value in untreated samples was found to be 0 mg/L. In treated samples, there is very slight variation showing no significant change in concentration. No recommended values were found by BIS standard. Nitrate (NO_3) is widespread in the environment. Water is naturally NO_3 deficient, which controls algae growth. NO_3 content found in raw waters (both sites) were well within the acceptable limit, this may be due to the water runoff may not contain NO_3 in nearby farm land. The relatively small amount of NO_3 found in natural water is of mineral origin, most of which are derived from organic sources and also from inorganic sources containing artificial fertilizers. Coagulant treated samples are also within the acceptable limit according to BIS standards. In high doses, nitrates are a health hazard that can cause methemoglobinemia (blue babies) which affects infants who are bottled-fed [Knobeloch et al., 2000]. The values ranged in our samples are 1-6 mg/L which are safe within the standards. Chloride (Cl) is one of the most important inorganic anions in water. Chlorine enrichment can affect the taste of water. Cl is not harmful to human health and is primarily associated with taste. According to BIS 10500, the acceptable limit for the presence of Cl content in water is 250 mg/L, but this can be extended up to 1000 mg/L. In present work, collected water in both districts are safe within the range. Cl concentrations

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in SPS treated waters were found to be 10 mg/L. As a result they are safe to drink. Excess Cl (> 250 mg/L) in water gives a salty taste and becomes more and more objectionable as the concentration rises. It may also be due to Ammonia elevation. Sulphate (SO_4) is one of the less toxic ions. High concentrations of SO_4 can trigger diarrhoea, while low concentrations have a laxative effect and respiratory diseases. The concentration of SO_4 in the study area ranged from 2-5 mg/L. BIS standards as permissible and excessive concentration of SO_4 in drinking water is 200 and 400 mg/L, in the present work the obtained results are safe within the limit.

Biological Examination:

Fecal coliform is a rod-shaped and gram-negative bacterium. Fecal coliform in water is caused by fecal matter from humans or other animals. Large quantities of Fecal coliform bacteria in water are not harmful according to some authorities, but may indicate a higher risk of pathogens (any organism that can produce disease) being present in water. Before treatment with coagulant, the result showed the uncountable Fecal coliform in both districts. After treatment with coagulant, the Fecal coliform reaches 150 (decreases compared to pre-treatment). Hence the result shows the capability of SPS for the removal of bacteria in water [Babu and Chaudhuri, 2005]. Bacteria were not completely removed from the water sample using SPS. However, SPS helped inhibit the growth of microorganisms.

Characterization studies

XRD: XRD patterns of coagulant with Cu K_α radiation in the range of $10^o \leq 2\theta \leq 70^o$ are depicted in Figure 3. The XRD patterns showed no significant sharp peaks, indicating the amorphous nature of coagulant (Showmya et al., 2012).

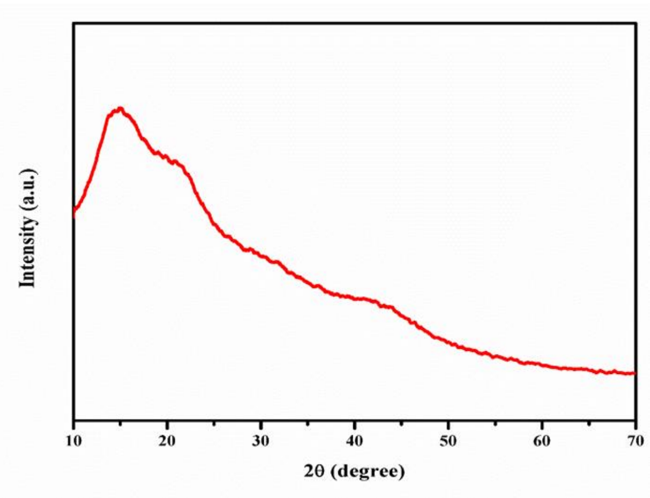

Figure 3. *XRD pattern of coagulant*

UV-Vis. By diluting SPS powder in ethanol it was subjected to UV-Visible Spectrophotometer study that was scanned at wavelengths ranging from 200 – 800 nm (Fig. 4). Most organic compounds undergo n → π* and π → π* transitions (200-300 nm) associated with the UV region. The absorbance spectra of coagulant exhibit a well-defined peak at 246 and 286 nm. These peaks are representing the specific metabolites like alkaloids and flavonoids (Patle et al., 2020)..

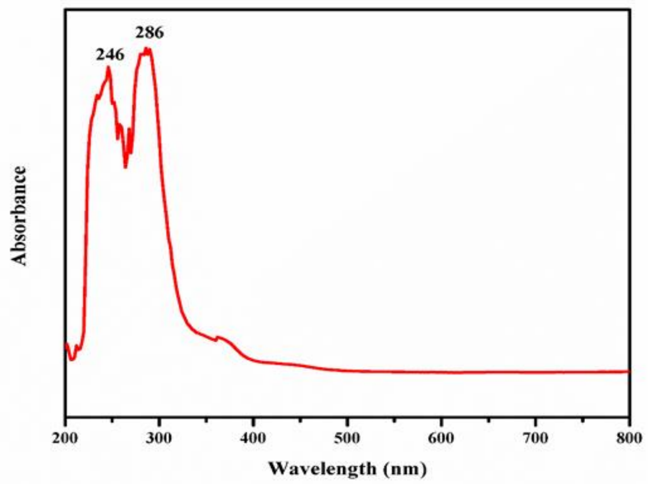

Figure 4. *UV-Vis spectrum of coagulant*

FT-IR. FT-IR analysis was performed in order to characterize the natural coagulant, SPS powder. FT-IR spectra of coagulant were recorded in the range of 500-4000 cm^{-1} to explore the nature of functional groups. Figure 5 shows the spectrum of SPS powder,

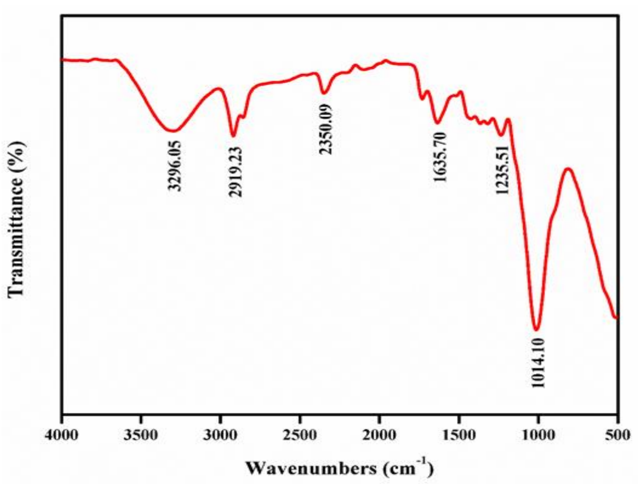

Figure 5. *FT-IR spectrum of coagulant*

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having an intense peak at 1014.10 cm^{-1} which is due to C-O stretching vibration of the ether group. A peak at 1235.51 cm^{-1} is due to C-N stretching vibration. Presence of H_2O is confirmed by bending vibration at 1635.70 cm^{-1}. The peak at 2350.09 cm^{-1} corresponds to C≡N stretching vibration (Benalia et al., 2022). Presence of alkyl group is confirmed by $-CH_2$ stretching vibration at 2919.23 cm^{-1}. The N-H stretching vibration of amine occurs at 3296.82 cm^{-1}. An IR spectrum reveals that the sample carries aliphatic grouping with ether linkages and nitro groups (Vishali and Karthikeyan, 2014).

Conclusions

Water quality monitoring can yield the benefits of data production to define basic environmental conditions, diagnose problems, determine potential actions and increase scientific and environmental awareness. The data generated will raise environmental awareness to the state regarding the status of the water. The demand for clean water is growing. SPS act as polyelectrolytes which can be used as natural coagulants to treat water. If proper measures are taken for the treatment of sewage before discharge, the population would remain healthy in the long run. SPS powder is suitable for home water treatment in rural areas of developing countries. SPS powder does not produce water without fecal coliform, but definitely produces 'low risk' water. Drinking water analysis for bacteriological and physico-chemical properties is essential for public health studies. Drinking water with chemical contamination is considered less important by regulators than microbial contamination because the negative health effects of chemical contaminations are usually associated with long-term exposure, while the effects of microbial contamination are usually immediate.

Statements and Declarations

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Author contributions. Sample analysis, data collection and implementation of writing the manuscript were performed by N L Sheeba. Sample collections were done by L Renuga Devi. The author E Selva Esakki analyzed and interpreted the data. The author S Meenakshi Sundar contributed to the design of this manuscript and supervised the work. The final manuscript was read and approved by all the mentioned authors.

Competing interests. The authors have no competing interests to declare that are relevant to the content of this article.

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