Environmental Pollution by Tea Processing

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Abstract— The tea industry is the major exporting item in Sri Lanka. So massive coverage of tea manufacturing factories and cultivated lands consist in Sri Lanka. This research is to focus on the environmental pollution regarding the types of wastages which generated as a by-product from tea processing industries. The classes & sources of solid, liquid, and thermal waste created a case study is the purpose of this paper during the tea manufacturing process.

Index Terms—By-Products, Environmental pollution, Solid waste, Liquid waste, Thermal Waste, Tea Processing, wastewater, Plantation.

1 Introduction

Every tea factory produces a large amount of tea waste, but tea waste buyer is lesser in number in the country. The residues derived from tea factories are called tea waste. If the tea waste is not disposed of properly, it can pollute the environment like soil, water and air. The cultivation of tea in Sri Lanka densely concentrated in the areas of altitude 1200m upwards which is calling highlands, elevation between 600m to 1200m as medium grown area, and low grown southern inland areas sea level to 600m [1]. Sri Lanka produces tea approximately 340 million kilograms per annum according to the previous studies [1] calming second largest tea producer in the world. The total cultivation of tea around 221, 969 hectares around Sri Lanka. The tea-growing areas spread throughout the country. The industry structure into two major sub-sectors: the vast estate and smallholder sub-sectors.

Waste management in the Sri Lankan tea factory is a significant challenge, and the current situation is that different types of waste generated are collected in the same area. The biodegradable and non-biodegradable waste collects at the same pit with no transparent tracking of the number of garbage generated. There is much energy lost through waste heat. Steam is a significant input in tea production. This study will identify the problems in the current waste management strategy. Then provide appropriate recommendations to assist in the development of a more efficient waste management processing system. The poor waste management system can pose the environment at a significant value. It will evaluate the effectiveness of the existing waste management system and identify gaps that can address to help design waste management that is more productive and efficient.

2 Process Description.

The tea-making process is an intricate one, starting with a good tea leaf-two leaves and a bud and resulting in the final tea leaf you see. Ceylon tea makes predominantly using the manufacturing process of orthodox tea, which has to practice for over a century. Although the following steps ensure the systematic production of tea, the skill of the tea-maker is crucial, as it is, he who decides on the exact timing, level and extent to which each step is conducted out, based on his experience. He wants what kinds of tea and which is a process it comes with practice, knowledge and experience and cannot merely replicate by anyone. The role of the tea maker is, therefore, vital [2].

2.1 Plucking

Expert tea pickers pick only the fresh bud leaf and the leaves presenting in Fig 1 in below, which is the key to ensuring that tea is rich in taste and appearance as well.

- **Purpose:** To choose two fresh tea leaves and bud

- **How it is done:** Tea pickers pick the tea leaves from the bushes by hand.

Fig 1: Tea Plucking [3]

2.2 Withering

Fig 2: Withering [4]

The plucked tea leaves try to bring into the factory, where they place in large withering troughs that fan hot air to reduce the tea leaf's moisture content, and it ensures flaccidity in the leaf. It is presenting Fig 2. It calls physical wither. There are also significant chemical changes that occur during this time such as the breakdown of molecules into smaller units that increase amino acids and flavor compounds, partial breakdown of walls among cells (cell wall permeability) that is essential for subsequent production stages. The plucked leaves will be withered for a least of 6 hours to ensure the adequate occurrence of this 'chemical wither [2].

- **Purpose:** To lower the plucked leaf's moisture content
- **How it is done:** The leaves are fanned in troughs with hot or ambient air.

2.3 Rolling

Fig 3: Rolling [5]

The primary objective of rolling is primarily to divide the leaf cells or compartments and to mix the leaf's chemical components with the enzymes. Fig 3 representing it and various types of rollers are used. The first roll is often called the 'pre-conditioning roll' and is also very pleasant. The pre-treatment roll's main action is the gentle expression of the leaf juice on to the twisted surface of the particles. These juices are drying up on particle surface to contribute to tea's black identity. Continuing rolling to achieve a thorough collapse of the leaf cells is designed. During the turning operation, a considerable amount of thermal energy generation by friction, but care must be taken to ensure that the temperature doesn't somehow exceed 35 ^{0}C (95^{o}F), because unwanted chemical and enzyme responses may happen at increasing temperature [2].

- **Aim:** To break up the leaf cells and mix up the leaf's chemical properties.
- **How it is done:** Pressure on the leaf is applied in stages in a Roller Using a rotational movement.

2.4 Fermentation/Oxidization

Fig 4: Fermentation/Oxidization [4]

When it is spread over such a surface of the planet and left to allow oxidation or what is called fermentation, the leaf sifts towards the Roll Breaker. The fermentation process represents a series of complex chemical processes which begin at the point in time when the leaf in the roller is damaged. The breaking up of cells that cause the blend of the enzymes within the cell with the other chemical components results in a number of reactions. Fig 4 represents fermentation process and Another very important thing about polyphenols is their oxidation. Some flavor compounds are formed as additional reactions occur during fermentation [2].

- **Purpose:** To allow the macerated leaf to oxidize or ‘ferment’ which is where important chemical reactions take place.
- **How it is done:** In a Roller applies pressure on the leaf in stages, using a rolling motion.

2.5 Firing/Drying

Fig 5: Firing/Drying [5]

The firing process representing Fig 5 and it helps to removes all of the moisture in the leaves and stops fermentation by hurting the enzymes. Furthermore, the tea flavour is 'balanced' during firing due to the removal of some of the lesser desirable low boiling compounds, thus accentuating the presence of higher boiling compounds that are more useful[2].

- **Purpose:** avoid fermentation in the tea leaves and the chemical processes.
- **How it is done:** The fermented leaves pass through the dryer, producing intense heat.

2.6 Sorting & Grading

Fig 6: Sorting & Grading [8]

By giving them through sifters, the fired tea leaves are sorted into the size of particles that sift them through various meshes which is representing Fig 6. This helps to classify the teas into the various grades – Dust, Pekoe, B.O.P. etc[2].

- **Purpose:** To sort the tea leaves into the desired grades.
- **How it is done:** The tea leaves are sending through different sifters and mesh sizes.

2.7 Tasting and Assessing

Fig 7: Tasting and Assessing [9]

The tea is made and then tested, evaluated by the tea-maker which is representing Fig 7. The experienced tasters to ensure that it meets all the quality standards regarding the appearance of the leaf, the aroma, the colour of the cup and the appearance of the tea[2].

- **Objective:** To assess the tea's quality, taste & character.
- **How it's done:** evaluating the brewed tea, analyzing the brewed tea leaf and the alcohol color.

3 WASTE GENERATION

It is essential to enhance the design of waste handling and gathering equipment to evaluate the physical, chemical, and thermal characteristics of the waste and maintain compliance with regional and national regulations when choosing the possible way to generate waste. To understand how much wastage is being developed. It is essential to undertake a study of the characterization of waste according to techniques approved international level. This means describing the type (composition) and quantities (generated or produced) of ignoring a waste stream. The current situation is that various types of waste produced are collected in the same area. The present situation is that multiple types of waste produced are collected in the same place. The organic and inorganic waste is collected at the same pit, and the number of wastes produced is not tracked. There is much energy lost through waste heat. Steam is an essential input in making tea. Here we will identify the existing waste management system gaps and provide the required changes to help develop a much more cost-effective waste management strategy. Poor management of waste can raise health concerns for workers and the environment at massive. Therefore, these types of waste can be categorized into three main parts: released in tea factories as [10].

3.1 Solid Waste

The sources and amounts of waste can be identified through various stages of tea production. These stages are the offloading bay, withering, processing, firing, sorting and packaging. Table 1 consists what are types of wastes in given below.

Table 1: Type of the waste produced at each stage of tea cultivation [2]

Source	Waste	Waste type
Leaf collection	Green leaf Gunny bags	Organic-Inorganic
Withering	Green leaf	Organic
Maceration (C.T.C.)	Green leaf Metal chips water	Organic Wastewater
Fermentation	Pekoe dust Heat	Organic Thermal
Drying	Pekoe dust Heat	Organic thermal
Sorting	Pekoe dust paper	Organic & organic

Especially solid wastes are produced as a by-product in the tea industry. One or two companies purchase a little amount of solid tea waste for the extraction of caffeine. The rest of the by-products are deposited in one corner of the tea factory or the tea garden areas. Decaffeinated tea wastes are discarded, but this by-product can be used as poultry and pig feed when considering the all types of tea wastes these are mainly categorized into two including,

- Factory Tea Waste (F.T.W.)

- Decaffeinated Tea Waste

Factory Tea Waste (F.T.W.) : During the tea processing in the factory, the fibre portion of leaves is removed and discarded as Tea Waste which also contains some tea leaves and dust. F.T.W. contains tannic acid that is one of the limiting factors for utilization of tea by-product in Poultry and Pigs feed.

Decaffeinated Tea Waste (D.C.T.W.) : Decaffeinated Tea Waste (D.C.T.W.) is the waste available in the Caffeine factories after the extraction of caffeine from Factory Tea Waste. The exciting feature of this industrial waste is that it contains little quantity of tannic acid (0.4–1.0% on a D.M. basis)9. If the D.C.T.W. is washed with boiled water, then it becomes good feed for Poultry, Pig and Fish [1].

3.2 Liquid Waste

Liquid waste is produced in tea processing, mainly from the factory's cleaning processes. There are two types of clean - up, major and minor cleaning, done during tea processing. Major factory cleaning is performed weekly, which involves the entire factory cleanup, while minor cleaning is performed daily and involves cleaning different sections such as the footbath.

3.3 Thermal Waste

Diverse heat losses occur in the processing of tea. These include heat loss from dry flue gas, heat loss due to hydrogen, absorbing heat due to air moisture, heat loss due to power moisture and radiation losses. Usually, the amount of heat lost during tea processing is lost through the flue gas at 14.52%, followed by heat lost due to hydrogen in the fuel at 6.62%. The smallest amount of heat loss occurs because of the fuel liquid at 1.1.72% [1].

3.4 Waste Handling

Management of solid waste

During tea processing, solid waste was produced at different stages, which were mentioned in waste management. In the tea factory, biodegradable wastes are disposed of in a landfill, which is overflowing. The entire waste collected has been discharged in the rubbish bins. Dust collected from the wrapper and sorting area, the dry leaves from the leaf collection center, and the scrap metals from the broken-down mechanical components were included in the pit's waste. At some point, the yard and pit were blended with waste products. Currently, the amount of scrap metal is not tested and has no specific benefit. The waste at the factory is often not segregated in terms. Sometimes the waste at the factory has not been segregated in terms of the type and amount. In particular, comparisons between the expected data calculated from the tea production mass balance and the actual data measurements. Most of the time, the fractions of desired made tea were lower than they made tea, and the quantities of expected solid waste were more significant than the actual amounts collected.

Thermal Waste Management

The boiler efficiency of the boiler can be calculated using the indirect method, also called the heat loss method, when evaluating heat waste management's effectiveness. The most extensive heat loss enhancement was due to dry combustion gases, whereas the lowest amount was found to be due to heat loss due to fuel moisture. Installing an economizer is an effective method to experience a large amount of heat energy loss during their

operation.

Tea waste and the issues related to environmental pollution

Especially in industrial tea companies, effluent has become a major threat increasing the rate of environmental pollution. When we consider effluent, it is a wastewater discharge from an industrial plant that can be either untreated or treated flowing from industries or sewers. It is waste from an industry that takes a form of a liquid in nature. It may result from a different array of pollutants like heavy metals, dyes, phenol, pharmaceuticals, and pesticides. When the wastes or pollutants are discharged from industries, they find their way to lakes, rivers, and streams that affect wildlife, humans, and plants. These pollutants, like those in streams and rivers by chemicals, are critical to the current generation.

Therefore, especially through surface runoff, the industrial effluent flows into the river, thus contaminating the water. When it rains, the water runoff sweeps away dirt to the rivers through the drainage channel, which discharges to the river. This runoff carries various wastes generated from the factory contamination water and, therefore, leads to habitat degradation. Industrial pollutants that comprise of wasted and effluents are majorly the primary causes of nearby rivers. The near pollutants from industries alter the chemical, physical, and biological composition of rivers to their immediate water bodies. Pollution of water bodies denies community access to both social and economic benefits. Polluted water decreases the recreational activities practiced, such as swimming. Besides, many associated public health problems come with the pollution of water. Some of the policies on effluent and emission have been established to curb the amount of pollution in a discharge unit towards the water surface or discharged to the water surface.

Disposal of waste' means 'to get rid of waste'. Waste disposal should be done scientifically. There are various methods of disposal of tea waste. Some of the essential modes of tea waste disposal,

- By selling
- By exporting
- By using the feed for poultry
- By using the feed for fish
- By separating the bioactive chemical components
- By utilizing it in the manufacture of caffeine or instant tea making
- By using for Bio-nutrient and Bio-fertilizer
- By burning

By Selling : We can dispose of the factory tea waste by selling to the caffeine industry. In Siliguri, one industry is present who buys the factory tea waste for extraction of caffeine, and they supply it to the pharmaceutical industry. Rate of Tea Waste There is no fixed rate determined by the Tea Board of India for the sale of tea waste. Generally, 25/- to 30/- L.K.R. profit margin could be achieved by selling one kg of tea waste in this region. In this region, a large amount of tea waste is deposited in tea factories, and tea growers will be benefited financially by selling it.

By Exporting : By exporting, one can dispose of the factory tea waste in other places where available caffeine industry is present. Assam is also one of India's states where a considerable number of caffeine industries are

present, and they've always been on the lookout for factory tea waste. Instant Tea Processing Tea wastes are used for the production of instant tea. Caffeine is separated from tea waste before instant tea manufacture10. In the process of production of instant tea from tea waste, excess tannin is also reduced.

Using Feed for Poultry and Pig, one can use the factory tea waste after the separation of caffeine. Decaffeinated tea waste has immense potentiality for the preparation of poultry and pigs' feed. Factory Tea Waste showing the highest level of tannic acid beyond 5% has a deleterious effect on broiler chicken's growth and performances. Tannic acids possibly act as anti-nutritive factors in broiler chicken, so the existence of tannic acid in tea waste might perturb the growth of those animals. This kind of food also increased the immune response in finishing pigs and increased the hens' egg-laying capacity.
Using the Feed for Fish Locally, one can use the decaffeinated tea waste as a fish feed with a mixture of mustard cake and water, as revealed from our survey report. D.C.T.W. contains eight times lesser tannic acid content than F.T.W. so that D.C.T.W. can be effectively used as fish feed for growth and development.

By Separating the Bioactive Chemical Components Considering the large-scale availability of tea waste in this region, both F.T.W. and D.C.T.W. can be used as a feed source for livestock poultry after separating the toxic chemical components up to tolerance level. For example, a 5% level of tannic acid or phosphorus present in the tea waste showed stress tolerance if used as livestock feed. Fluoride and pesticide residues can also be found in tea waste. Identification of toxic and bioactive chemicals from the waste can be made by using UV-Vis, Fluorescence Spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), Nuclear Magnetic Resonance (N.M.R.), Atomic Absorption Spectrometry (A.A.S.) and Atmospheric Pressure Chemical Ionization-Mass Spectrometry (LC/ APCI-MS)15. The subsequent separation of chemicals from the waste can be made using Low-Pressure Liquid Column Chromatography (L.P.L.C.), Gas Chromatography (G.C.), and High-Pressure Liquid Chromatography (HPLC) [1].

Further, Tea waste can be used as a low-cost adsorbent for the removal of Cu and Pb from wastewater16. Activated tea waste can also be used as a potential low- cost adsorbent for the removal of ρ-nitrophenol from wastewater. The chemical analysis and separation of tea

Waste can be performed at the University of North Bengal, Darjeeling and Tea Research Centre of Tea Board, New Jalpaiguri of this region. Re-processing of tea fiber waste for the production of valuable biological products might be another option of its utilization because tea fiber waste contains several polyphenols and cellulosic materials as analyzed previously17. Recycling of plant fibers obtained from Calotropis Gigana tea through enzymatic hydrolysis of cellulose for bioethanol production has been reported very recently18. Also, there are appropriate scientific methods for evaluation of physical and mechanical properties of wood fibres as already implied on Quercus, Fagus, Alnus and Fraxinus hardwood plants19. For improvement of tea fibers isolated from waste, those attributes might be standardized with functional group modification of biopolymer components.
It is Utilizing in the Manufacture of Caffeine or Instant Tea Making After the chemical separation. Caffeine is extracted from the factory tea waste and utilized in the pharmaceutical laboratory.

By using for Bio-nutrient and Bio-fertilizer, most of the tea factories of this area utilized their tea waste in the

plantation area. Due to caffeine, tea waste increases the acidity of the soil. But if we mixed the factory tea waste with 5% urea and cow dung for at least 45 days and kept in soil, then it will be converted into a good bio-nutrient and bio-fertilizer. Tea waste also contains significant amounts of n-triacontanol20. The compound n-triacontanol has tea plant growth-promoting properties and might also regulate different other physiological properties like the formation of leaf primordial and development of primary leaves.

By Burning In some cases, the factory tea waste can be disposed of by burning.
As well as a government when creating policies with rules and regulations, they can implement the implementing rules and regulations relating to the disposal of tea waste such as allowing no one to discharge of any tea waste except in the following way, namely.

- By selling to any person holding a license
- By exporting through proper channel

Suggested Protocol for Managing Tea Waste To prevent damage, losses or contravention of legislation, it is essential to manage waste properly.

A suitable protocol of waste management is,

- There should be proper identification, nature and quantity of tea waste for further steps.
- The producer must not allow any person/company to dispose of tea waste without having a proper waste management license.
- The producer must provide an authenticated detailed document explaining the tea waste before the transfer of the same.
- There should be no excuse of exemption on behalf of the producers in tea waste management.
- There should be scientific and eco-friendly guidelines on disposal of tea waste.
- Government and local bodies need to be more proactive in the management of tea waste.
- Environmentalists, researchers, as well as the common people, need to be much aware of the hazards of tea waste.

Normally the highest amount of waste is produced at the withering stage, followed by sorting due to fanning and pekoe dust, packing due to packaging materials and worn-out sacks and papers, processing and firing due to spillages and dust.

4 Conclusion

The tea industry is the primary industry in Sri Lanka. So, the number of sectors is getting higher value with waste generation as by-products. Sri Lankan government makes a system forget that waste for agricultural institutes and biogas production companies. Then other by-products, disposal by environmentally friendly methods must be used in those industries. Landfilling, compost pit, is the primary use of Solid Waste in the Tea industry in Sri Lanka due to agricultural country. Agricultural centers are also generated composts using that waste materials to continue house gardening for country people to grow their crops. Liquid wastes are used to improve biogas generation. Because decaffeinated waste has an acidic condition, another thing is biogas power

plants, which generate power and add that electricity to the main grid. (Steam generation is doing by firing biogas).

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