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Methane Emission during Rubber Production in Sri Lanka, its Quantification and Conversion to Useful Energy

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Abstract : Rubber was introduced to Sri Lanka in the late 19th century and now the country has around 138,000 ha under rubber cultivation, 68% of which are owned by smallholders. They are responsible for 77% of the country's rubber production.

Manufacturing of rubber starts with tapping for latex and during the process of converting latex to end products, large volumes of water and chemicals are used. This results in a lot of liquid waste, which is systematically handled in larger factories, but smallholders discharge such waste without any control. This gives rise to Methane emissions. Methane is a Green House Gas (GHG) environmentally hazardous and these emissions over a ten year period were found to be around 189,000 $MTCO_2e$. This situation has prevailed from the start of the rubber industry, yet no meaningful steps have been taken to find a solution.

Provision of anaerobic digesters to smallholders for the collection/treatment of wastewater appears to be the best solution. Gases will then separate and collect in the tank. Gas mixture is similar to biogas and the energy potential available would be around 9GWh/year.. It is recommended that a project be launched with funds sourced from international agencies for GHG emission mitigation, where CDM/CER stands out as the best option. The project has the potential to raise around US$ 900,000 from the Carbon market.

Keywords: CDM/CER, GHG, Methane, Rubber, Smallholders

1. Introduction

Rubber is a major economic crop of Sri Lanka and there were around 138,526 ha of land under rubber cultivation by 2022, 68% of which are owned by small holders, i.e., those who own less than 10ha. Rest is known as Estates owned mostly by private companies. Production of rubber starts with the tapping of the rubber trees to obtain latex, a liquid which is then converted to end products such as sheet rubber, crepe, etc. During this process, large volumes of water and various chemicals are used. This results in large quantities of liquid waste and effluent. In big or even moderate sized rubber factories, such waste is systematically handled through water treatment plants. However, the situation is different in the case of smallholder owned rubber factories, They discharge untreated rubber effluent waste into the surroundings, thereby giving rise to Green House Gas (GHG) emissions causing health hazards and damaging environment. There are many government institutions associated with the rubber industry, but yet no plans have been even proposed to remedy the situation.

The objective of this paper is to analyze the grave situation highlighted above and propose a win-win solution acceptable to all stakeholders and to the society.

2. Brief History

Rubber was introduced to Sri Lanka in the late 19th century by the colonial rulers as a replacement crop for coffee, which was being destroyed by a plant fungus disease. The first seedlings were planted at the Gampaha botanical gardens in 1876. Encouraged by the growth and the subsequent flowering of these trees in 1881, a team that included Sir Joseph Hooker was entrusted with the task of examining the suitability of selecting rubber as the replacement crop for Ceylon.

Based on the research carried out, colonial government selected rubber as an economic crop to replace coffee, incidentally, becoming the first South Asian country to grow rubber. Accordingly, in the year 1893, 90,000 seeds were distributed for planting and by 1923 approximately 180,085ha had been under rubber cultivation [1].

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2.1 Rubber Plantations

Rubber is a major economic crop in Sri Lanka and in 2022 there were 138,526 ha under rubber cultivation [2].

Rubber plantations in Sri Lanka can be broadly classified into two groups, i.e., as "Estates" where land under rubber cultivation exceeds 10ha and the rest as small holdings. Statistics suggest that small holders contribute 77%to the total production [3]. They produce mainly sheet rubber or sell as latex to companies who have established networks for collection of latex.

2.2 Sheet Rubber Production Process and Emission of Methane

Production process for large companies as well as for the smallholders for whatever the product, commences with the tapping of the rubber trees. Early in the morning, tappers go from tree to tree and make a cut on its bark, immediately below a cut already had been made. A special knife is used for this and the cut is made for half the circumference of the trunk, slanting the cut down from left to right at an angle of around 30° starting at the highest point convenient to the tapper. Each subsequent cut is made immediately below its predecessor. With this operation latex starts to exude along the cut, flows down and gets collected in a suitable container, most often a coconut shell fixed onto the tree. Within about three hours after tapping, tappers go back to the trees, collect the latex into buckets and bring it to the collection centre.

Latex is a mixture of rubber particles made up of a negatively charged membrane that surrounds small groups of rubber molecules and water. As membranes are of the same polarity, they will repel each other and will not coagulate. However, if latex is exposed to air, coagulation will take place very slowly due to the action of bacteria present in latex, which forms acid that has the positively charged Hydrogen ions (H^+). These H^+ ions neutralizenegatively charged membranes and allow them to collide with each other, thereby letting the rubber molecules to combine with each other.

For rubber industry to be economically /financially feasible, coagulation process has to be faster and this is done by providing H^+ ions through the addition of Acetic acid (CH_3COOH) to the latex/water mixture.

$$CH_3COOH = CH_3COO + H^+ \qquad \text{... (1)}$$

When making sheet rubber, standard quantities of latex and water are poured into aluminum/plastic trays and comparatively very small quantity of acid also added to each tray. As explained above, coagulation will take place and would yield rubber lumps, With the loosing of H^+ ion, Acetic acid will get converted to Acetate (CH_3COO). Workers then flatten the rubber lumps using their palms to make it thinner as possible, and finally rolled using rolling machines with steel rollers to make rubber sheets of desired dimensions.

While flattening the lumps with palms and rolling them in the machines, wastewater containing acetate and possibly even traces of acetic acid, would ooze out. In almost all small holdings, this wastewater is allowed to drain away. As there is no proper management, such water flows into the surroundings and gets collected in puddles, garbage dumps, paddy fields and almost everywhere. Bacteria present at these locations assist in starting anaerobic digestion in oxygen-deficient environment converting Acetate to Methane (CH_4) [4].

$$CH_3COO + H_2O = CH_4 + HCO_3 \qquad \text{... (2)}$$

Carbonic acid will decompose to CO_2 and water. The emitted gas comprises 57.7%–60.8% Methane, 14.5%–31.5% Carbon Dioxide, 10.8%–24.7% Nitrogen, and 329–423 ppm of Nitrous Oxide.[5]. In Sri Lanka, rubber smallholder installation will not produce nitrous compounds, as Ammonia is not used for preservation,when making sheet rubber.

2.3 Rubber Sheet Drying

The last step in the production process is sheet drying. Smallholders use smokehouses for this activity. The old-fashioned smoke house is a small chamber with a pit in the middle in which the fire is set up. Rounded wooden poles are fixed from wall to wall on which the wet rubber sheets are hung. The efficiency of heat transfer of these smoke houses, which are not built according to any standard is very poor and has been found to be around 31%[6].

Having recognized the need for efficiency and quality improvement in the production process, Rubber Research Institute of Sri Lanka (RRISL) introduced a new sheet drier, which had the capability of drying 60 nos. of 500g sheets a day whilst ensuring best quality. It was a step in the right direction with a higher efficiency of 52% [6], but the heat source of the appliance, the sawdust burner was a drawback. Transporting, storing sawdust and the preparation of the burner were somewhat cumbersome and time consuming and did not become very popular among the smallholders.

2.4 Energy Required for Sheet Drying

Energy required for sheet drying is worked out using the field data. It has been found that sixcubic yards of dried firewood is required to dry (0.5x900) kg of sheet rubber. It is assumed that the ambient temperature is 25^0C and the smokehouse temperature is maintained at around 60^0C.

Calorific value of firewood = 1400-2000 kWh/m^3
Moisture content = 20%
Average Calorific value of firewood (kWh/m^3)
= (1400+2000)/2 kWh/m^3
=1700 kWh/ m^3
1 cubic yard = 0.7646 m^3
Calorific value of firewood (kWh/y^3)
= 1700 x 0.7646 kWh/ y^3
= 1300 kWh/ y^3
Heat produced by 6 y^3 of firewood
= 6 x 1300 kWh
=7,800 kWh

Part of this heat will be used to heat the moisture content and 31% is heat transfer efficiency [6].
Heat energy used for sheet drying
= (7800 x31%) kWh
=2418 kWh

3. Methane the Green House Gas (GHG)

Methane is classified as one of the main GHGs. It traps heat in the atmosphere acting like a blanket insulating the Earth, causing global warming, harming the environment and effecting climatic change. All these gases remain in the atmosphere long enough to become well mixed, meaning that the amount that is measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions. The heating effect imparted by the gases is measured with the unit GWP (Global Warming Potential) where CO_2 is taken as the reference (or 1). Intergovernmental Panel on Climate Change (IPCC) updates GWP values based on new scientific knowledge of gases, and the value for Methane is 28 for 2020–21 onwards. ([7]

GWP for Methane has had an increasing trend from 2008 to 2014 onwards, but in this study, it will be assumed to remain constant at 28 for the project period.

In order to compute and compare emissions/heating impact by different GHGs, a standardized measure (CO_2e: carbon dioxide equivalent) has been introduced. The CO_2 equivalent (CO_2e) of a GHG refers to the amount of carbon dioxide (CO_2) that would have the equivalent global warming impact over a specified timeframe. This can be worked out by multiplying the amount of the GHG (kg) by its GWP.

Though it is amply evident that GHGs are harmful and destructive, the ordinary villagers living in the rubber growing areas (smallholdings) or even urban dwellers who are supposed to be better educated will not consider this as a threat whole world is facing. However, those villagers in the rubber growing areas will be quite aware of the big stink wastewater creates, its health hazards, pollution of ground water etc. They have been forced to accept these unpleasant experiences as part of their life, with the only positive outcome being the excellent fertilizer this process yields as sludge.

Table 1 - Summary of the GWPs for different greenhouse gases by year

Greenhouse gas	AR2 GWPs (2008–09 to 2014–15)	AR4 GWPs (2015–16 to 2019–20)	AR5 GWPs (2020–21 onwards)	2020–21 GWPs / 2019–20 GWPs
Carbon Dioxide	1	1	1	0%
Methane	21	25	28	12%
Nitrous Oxide	310	298	265	–11%
Perfluoromethane (Tetrafluoromethane)	6,500	7,390	6,630	–10%
Perfluoroethane (Hexafluoroethane)	9,200	12,200	11,100	–9%
Sulphur Hexafluoride	23,900	22,800	23,500	3%

Source : Clean Energy Regulator of Australia

3.1 Control on Methane Emissions – Action up to Now

It is now abundantly clear that the rubber manufacturing process has serious environmental hazards, and this is mostly associated with the wastewater discharged during the process. As explained above, wastewater, if discharged untreated, will be environmentally hazardous. This undesirable situation will be a feature in any rubber manufacturing factory, and possibly under pressure from the Central Environmental Authority (CEA), almost all large or even moderate sized rubber manufacturing factories have installed water treatment plants. To enhance the importance of wastewater treatment, in 1995, RRISL also commissioned a pilot water treatment plant in Darton Field Estate, apparently at half the cost of a normal plant. It is stated that RRISL received USD 30,000 from the Sri Lanka Council for Agricultural Research Policy for the project.

4. Rubber Smallholders

Rubber smallholders are a major stakeholder in Sri Lanka's rubber industry[3]. Whilst playing this important role, knowingly or unknowingly, they have got used to discharging wastewater giving rise to Methane emissions. Though it is evident that some control is being exercised over the discharge of wastewater in estate owned rubber factories, there is hardly any evidence to say that neither the many government institutions associated with the rubber industry nor the CEA has focused their attention on this unhealthy practice of the smallholders.

In Sri Lanka, there is no hard and fast definition for Rubber smallholdings. It has been generally accepted that those who own rubber lands of less than 10ha fall into this category. Some may own 5-6 trees and the latex tapped may be sufficient for 1-2 sheets. He may either take latex to a nearby factory or makes sheets at home up to the rolling stage. At any location, if sheet making is done up to flattening stage, (where the effluent discharge is highest), Methane emissions would take place, but the volume of Methane produced would depend on the amount of latex processed. Smallholders may not decide to invest on a fully fledged sheet making factory unless production capacity reaches around 40-50 numbers of 500g sheets a day, Sri Lanka's rubber smallholders continue in this industry amidst many adversities, to name a few, unsteady/unfavourable prices, vagaries of weather, high labour costs, excessive fertilizer prices and in addition bullying by the state authorities. In this backdrop they will not have any breathing space even to think about finding solutions to overcome the environmental hazards they themselves create. Hence addressing this grave problem is an immediate necessity, but the end resulthas to be a win-win solution.

4.1 Methane Production by Smallholders– an Estimation

Research on Methane production during rubber processing and many related subjects has been done by almost all rubber producing countries in South Asia. Special mention should be made on the research carried out by Dr. James Jacob of Rubber Research Institute of India who has taken the lead in this regard and has published their findings[8]. Many projects have been successfully implemented based on the recommendations given therein. It is proposed to quantify the volume of Methane emissions in Sri Lanka's rubber smallholder sector using the norms and data so published.

4.1.1 Assumptions

Following assumptions are made for the calculations:

1. Uncontrolled Methane emissions from rubber wastewater occur only in the rubber smallholder sector.
2. When producing 1kg of sheet rubber 8 Litres of effluent water will be produced and each Litre of effluent has the potential of producing 1Litre of a mixture of gases containing mainly Methane, Carbon Dioxide and traces of other gasses (At 25 ^{0}C Normal Temperature and Pressure-NTP)[8].
3. Methane content of the above gas mixture is 0.6 Litre (at 25 deg^{0}C NTP) [5&8]
4. Density of Methane is 0.657 kg/m^3 at 25^{0}C
5. Smallholder sector produces only sheet rubber.
6. Total rubber production in the year 2022 had been 70,867MT, 49% of which is sheet rubber [9].
7. Smallholder sector is responsible for77% of the total production[3].
8. Assumptions 5,6,7 will remain the same over the next 10 years.

9. Anaerobic digesters and the associated systems will have a life period minimum of 10 years.

4.1.2 Estimation of Methane being produced at smallholder rubber factories

Volume of gas from 1kg of sheet rubber
= 8 x 8 Litres
= 64 Litres
Yield of Methane per kg of rubber sheet
= 64 x 0.6 Litres
= 38.4 Litres
Weight of Methane produced per kg of rubber sheet = 38.4 x 0.657 g
= 25.23 g
Total quantity of rubber sheets produced in the year 2022 by smallholders
= 70,867 x 49% x 77% MT
= 26,738 MT
Methane emissions by smallholders
=26,738x25.23 MT
= 675 MT

Let us say that an anaerobic digester tank is installed at each smallholder rubber factory and the rubber wastewater is diverted into that. Then, as explained in Section 2.2, methane and the other gases will be produced within the tank and get trapped in it, thereby preventing the release of Methane to the atmosphere, as was happening before. Total quantity of Methane collected in the tanks will be the sum of Methane volumes collected in each tank, which will be 675 MT over a 12 month period. Therefore, with the commissioning of the anaerobic digester tank, release of 675MT of Methane to the atmosphere will come to a stop. It will continue to be so for the next 10 years, assumed life time of the tank/piping system, making the total quantity of Methane prevented from being released to the atmosphere by the project 675 x 10 MT = 6750 MT, which will be equivalent to 6750 x 28 = 189,000 $MTCO_2e$.

Table 2 - Projected Methane Emissions – Sri Lanka (million metric tonnes carbon dioxide equivalent ($MMTCO_2e$)

Sector	2020	2035	2050
Biogas	3.222	3.555	3.711
Oil & Gas	0.003	0.004	0.004
Other (Non-GMI)	7.723	8.966	10.019

Source: :https://www.globalmethane.org/partners/detail.aspx?c=srilanka

4.1.2.1 Estimation of Methane volume of a typical smallholder rubber factory - 900 Nos. 500g sheets

Projected Methane emissions for Sri Lanka are shown in Table 2. . Compared to the projected total emissions in a 12 month period, emissions (189,000 $MTCO_2eq$) from rubber smallholders appear to be insignificant, but small or big methane emissions are bad. Hence, efforts should be made to prevent the GHG releases, so long as they are workable and financially viable.

One alternative will be to request each smallholder to install an anaerobic digester, but with their hand to mouth existence, they will not comply with that, unless the project is financially attractive. Their benefits are the biogas produced, cleaner surroundings and psychological satisfaction that they are taking part in a worthy admirable cause. The only financial benefit is the energy from biogas and hence an attempt was made to quantify the same.

Weight of Methane produced per kg of rubber sheet =25.23 g
Total weight of Methane produced by (900 x 500 = 450kg) sheets = 25.23 x 450g
=11,353.5 g
Calorific value of Methane = 13.9 kWh/kg
Heat potential of Methane
=13.9 x 11,353.5/1000 kWh
= 157.8 kWh

The reward the smallholder gets by installing an anaerobic digester is only 157.8 kWh, hence it is very unlikely that they would take any interest in such measures. Nevertheless it should be noted that, as smallholders produce 26,738 MT of sheet rubber per year, then a total of 9376MWh $(26{,}738\text{x}10^3)\text{x}(157.8)/(900\text{x}0.5)$ kWh of renewable energy/year will be available to the country.

5. Way Forward

It is now evident that Methane emissions from smallholder rubber factories, estimated at 189,000 MTCO2e, could be extracted from the wastewater discharges employing bio-gas technology. To achieve this, an anaerobic digester tank will be required for each smallholder factory and considering the large number in the industry and that they are scattered in many parts of the island, a fully-fledged project has to be formulated. One of the government institutions could be entrusted with the formulating and implementing the project, but funds may not be readily available locally. Many international agencies have been established for supporting Methane emission reductions, but it is recommended to initiate action in accordance with the Certified Emission Reductions (CERs), a key componentprovided under Kyoto Protocol's Clean Development Mechanism (CDM) for the emission reduction in developing countries.

5.1 CDM and CER

CERs are generated through projects implemented in developing countries that reduce GHG emissions or enhance carbon removals. These projects must be approved and monitored according to CDM standards.

5.1.1 Project formulation

A project proposal for arresting Methane emissions and converting that to useful energy in the rubber smallholder sector, as described above, has all the required ingredients of a project, with which CER could be generated. Availability of biogas at no additional cost allows the smallholder to use it for household work, which amounts to the replacement of firewood or LPG. Biogas production could be enhanced by using unwanted organic matter such as coconut husk, leaves, cow dung, etc. promoting cleaner surroundings, as additionalfeedstock. Perhaps, this may help to produce sufficient energy to dry at least a sizable part of the sheets, thereby saving firewood. This will pave the way to reduce the workload on the inefficientsmoke houses, which indirectly amounts to reforestation

5.1.2 Verification

When the project report is submitted, it will be verified/audited by an independent third party to ensure transparency and credibility. Once verified, the project will receive CERs equivalent to the amount of emissions it has reduced. Each CER represents one ton of CO_2 equivalent that has been avoided or removed.

5.1.3 Trading

CERs can be traded on the international carbon market. They can be bought by governments, companies, or other entities to offset their own emissions or to comply with regulatory requirements. Rates vary according to market conditions and has fetched USD 3-4 in the very recent past.[10]. This suggests that Sri Lanka could raise around 700,000 USD for mitigation of Methane emissions alone. With the benefits of renewable energy,fund raisingpotential of the project may exceed 900,000 USD.

Though, it is not within the scope of this study, it must be stated that Sri Lanka's smallholder rubber sector work practices remain the same as those were 100 years ago, except for the introduction of rain guards, whereas other South Asian countries have moved onto robot age, with China introducing robot operated rubber tapping (STM32WL) ensuring a smart rubber tapping operation [11].

6. Conclusion

Environmental pollution due to Methane emissions have been occurring in Sri Lanka from the very first day rubber manufacturing started here. As the time progressed, it was identified that pollution is caused mostly by the wastewater discharge.

Though the situation appears to be under some control in big factories, there is no known evidence to say that any meaningful steps have been taken regarding the waste water discharges by smallholders. Their Methane emissions per year are around 189,000 $MTCO_2e$.
This could be arrested by guiding the smallholder to direct their wastewater to an anaerobic digester tank. Methane and the other gases emitted get collected in the tank and energy harnessed may be sufficient for household work to replace LPG or firewood. Total renewable energy would be around 9 GWh per year. If the tank could be fed with other organic matter as well, gas production could be increased and perhaps may become sufficient to dry sheets as well. However, expecting the smallholder to take the initiative in such a project is a daydream.
Methane emission reduction is considered as a topmost priority in the developed world and is being supported by many international agencies. Sri Lanka should grab this opportunity and venture into a project to plan, supply, install and commission anaerobic digester tanks and associated systems at all smallholder installations. Methane emission reduction achievable is estimated to be 189,000 $MTCO_2eq$,. CDM/CER appear to be the best avenue to source funds, and would fetch around US$900,000, but project developers should keep a close watch and be vigilant about the other funding agencies supporting the Methane reduction programs.

This is a win-win situation as the rubber smallholder would become the beneficiary of a project that will yield him with cleaner/pleasant surroundings, a bonus of renewable energy with which part of firewood/LPG could be replaced and the satisfaction of being an active participant which would benefit the whole world without drawing even a penny from his pocket or government coffers. It may be possible to improve the performance of the anearobic digestor by using other organic matter such as leaves and cowdung,which are available in plenty in villages. Launching a pilot project covering a village will be advantgous, as it would shed light on obscure areas, if there are any. Inally, though it is not within the scope of this study, authorities need to be remindedthat rubber smallholders are the backbone of the country's rubber industry, but their work practices remain the same as they were 100 years ago, whereas other South Asian countries have moved onto robot technology to improve the efficiency [11].

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