SANITARY WASTE:GENERATION AND DISPOSAL PRACTICES

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Chapter 1

Statistics on Sanitary Waste

According to the provisions of 3(41) of Solid Waste Management Rules, 2016, sanitary waste is described as waste comprising of used Diapers, Sanitary Towels or napkins, tampons, condoms, incontinence sheets, and any other similar waste. Statistics related to the quantum of waste generated and disposed of is very scarce in Indian context. As per a study conducted in 2018, by Arundati Muralitharan of Water Aid India, it's been reported that out of the 336 million menstruating women around 36% have access to sanitary pads and the rest use other materials. A rough estimate of total sanitary pads amounts to 12 billion pads per year.

It's a known fact that these sanitary pads take 500-800 years to decompose, around 1,13,000 tonnes of menstrual waste reach the Indian landfill[2]. As per Rule 17 of SWM rules, 2016, the duty of manufacturers or brand owners of disposable products, sanitary napkins, and diapers has been clearly stated. It's being necessitated that manufacturers or brand owners have to provide financial assistance to the local authorities for the establishment of the waste management system, also a system has to be put in place for the collection of non-biodegradable packaging that comes with sanitary products, providing a wrapper or pouch for disposal of sanitary napkins and diapers, emphasizes the recovery of recyclable materials from their products. Only two cities – Bengaluru and Pune – have laws on segregation of sanitary waste wherein the sanitary waste must be separately handed over along with the dry and wet waste of the household. A recent study conducted by the National Family health survey, has pointed out that the adoption of sanitary pads is growing steadily among the 15-24 age group[5]. As seen in Figure 1.1, it depicts the increased tendency of sanitary waste in five Indian states. In the context of a typical Indian setting, the same may be inferred. No data is available on how much diaper waste ends up in landfill,The diaper industry in India has grown with a CAGR of more than 20% from last five years from 2011-12 to 2016-17. Diaper market largely consists of baby diapers in India with more than 95% volume share whereas adult diapers have just started to foray into the mainstream market. It is regarded as a luxury good without reuse value, diapers are unaffordable for many people in India. According to the US-Based market research firm Expert Market Researcher, it's predicted that market value for sanitary napkins would touch USD 975.4 million by 2026. This is a growing concern in terms of waste management.

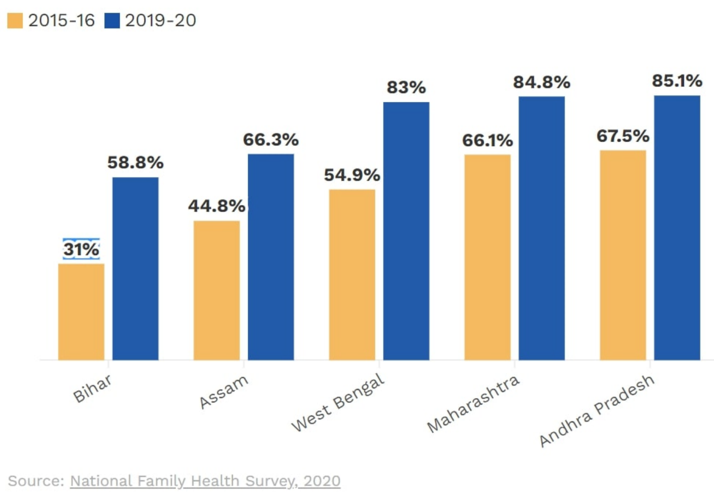

Figure 1.1: Use of "hygienic methods of protection during periods" by women aged 15-24 across 5 Indian States

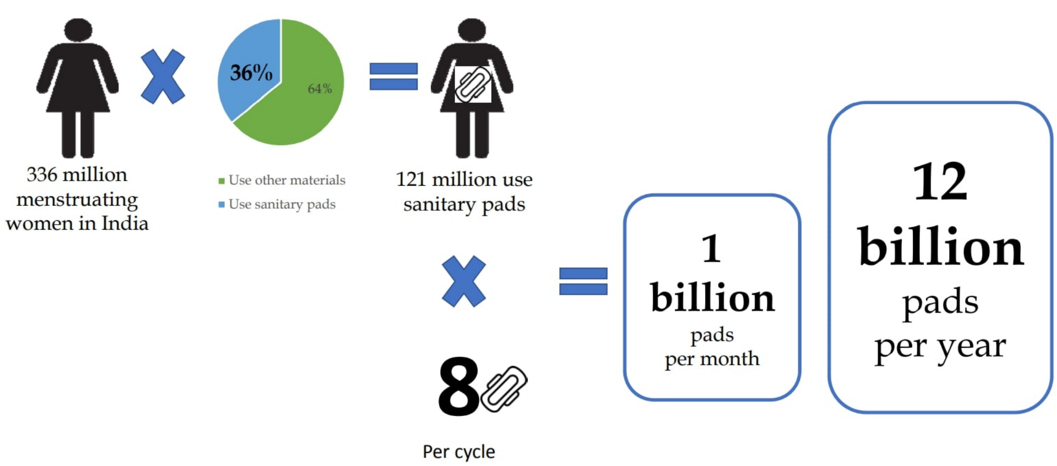

Figure 1.2: Sanitary Napkins waste load

Chapter 2

Disposal Pathways

2.1 Government Intervention in Disposal of sanitary waste

It has been stipulated by the Bio-Medical Waste Management Rules, 2016 to incinerate, autoclave items contaminated with blood and bodily fluids, including cotton dressing, soiled plaster casts, lines, and bedding to destroy pathogens. However, there's a growing concern among environmentalists that when these pads are burnt in the open or in incinerators, they release toxic chemicals such as furans and dioxin, which are known carcinogens. Recently National Green Tribunal had directed the statutory authorities to enforce the compliance of SWM rules along with the CPCB Guidelines for management of sanitary waste issued in May 2018, in the matter of Purva Parvin Bora & others Vs MoEFCC & others dated 12/03/2021. Amidst all this chaos, many states have come forward to resolve the problem by providing biodegradable sanitary napkins at an affordable price. Through this report, we would like to disseminate information regarding the complete lifecycle of sanitary waste right from generation to disposal. Many Municipal corporations in India have come forward to tackle this issue, recently New delhi Municipal Corporation has decided to install sanitary napkin incinerators (SNI) in 3,204 toilet blocks of 553 girls and co-ed schools under the Directorate of Education (DoE) and the Municipal Corporation of Delhi (MCD) to combat the taboo on menstrual hygiene, similar measures have been adopted by Navi Mumbai Municipal Corporation.

2.2 Harmful effects of Sanitary waste and disposal scenarios in India

Initially, it's imperative to understand why sanitary waste is creating so many problems, what are the ways in which we could get rid of them in an environmentally sound way. Soiled sanitary napkins have the potential to carry pathogens causing HIV and provide a favorable environment for the growth of Tetani[1], so it's important to destroy these napkins with minimal human contact. CPCB also provided safe and unsafe practices in the disposal of used sanitary napkins, the most preferred method is using small-scale incinerators and

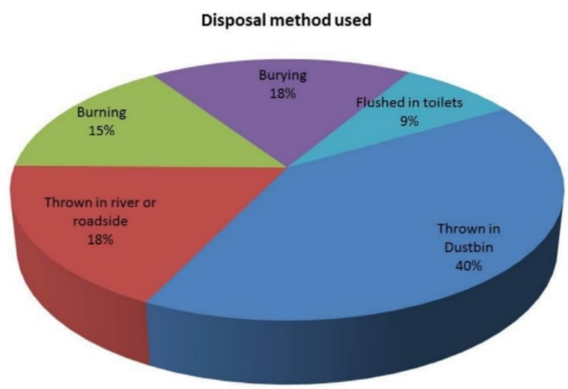

Figure 2.1: Current Disposal Practices

burning in health clinics. A practice that has to be avoided at all costs is wrapping them in paper and throwing them outside. It also has a social angle to it, social stigma attached to menstruation affects the sanitary waste disposal behavior of women in the country[6].In most rural areas, where women are still subjected to the prejudice of being considered impure while menstruating, this issue is further exacerbated.In some rural areas, deep pits or deep burial is done to get rid of the sanitary waste but such practices are only recommended for compostable pads. Soiled napkins are sometimes flushed down the toilet, due to lack of information on disposal facilities women even today flush used napkins in toilet. Figure 2.1 gives an overview of disposal practices in India

Incineration also has its own demerits, a recent study by scientists from Centre for Sustainable technologies from IISc Bengaluru have evaluated the CO and CO2 emissions from Single chamber sanitary napkins incinerator, these single chamber incinerators is used to promote source-level handling and disposal. It has been found out that by improving the design of air flow in the chamber and setting an operational temperature of around 600^oC, could bring these incinerators comply with CPCB emission guidelines[1]. Similar to used sanitary napkins, used baby diapers generation is very high and disposal pathways are cloudy. Biodegradation[3], pyrolysis and composting show potential as disposal mean to treat and recycle used diapers[4]. Lot of innovation has to be fed into this sector, these technologies are in the nascent stages, further studies have to be carried out to upscale these technologies, it should also be economically viable pathway.

2.3 Disposal Practices in other countries

2.3.1 Recycling

- Currently, the recycling of used diapers focuses on the separation of its plastic and organic fiber components which involves a series of complex processes, such as collection, shredding, sterilization, and separation processes

- Knowaste Ltd. is a company in the UK where the used diapers are shredded, agitated with a dehydrating agent, sterilized with autoclave technology
- Fater is an Italian company where the recycling processes involve sterilization and odor removal of the diapers under high-pressure steam. The superabsorbent material can be used as anti-flooding barriers and for gardening due to its adsorption properties
- In Japan, Super Faiths Inc. has invented a disposal system named as SFD conversion system, which recycles used diapers to produce fuel for biomass boilers
- PHS Group from the UK, has successfully developed a recycling system of diaper wastes into energy. The system is similar to conventional recycling, which involves mechanical separation, chemical treatment, and conversion of plastic to Refuse Derived Fuel (RDF).

2.3.2 Incineration

- Incineration is a full oxidative combustion where the wastes are burned at temperatures from 900 to $950^{o}C$, a good option for waste-to-energy processing
- In 2015, 1141 incineration plants operated in Japan, whereby 348 plants had power generation facilities to produce a total power of 1,934,000 kW
- Prevention of re-synthesis of dioxin during the incineration of sanitary waste is a key feature in the system. For the said purpose, an exhaust cooling compartment had been included in the advanced incineration system in Japan with flter bags and activated charcoal to eliminate and absorb dioxin from smoke and exhaust fume.

2.3.3 Landfill

- In Malaysia landfll sites have been built since the 1970s and currently Malaysia has about 170 waste disposal sites and 14 sanitary landfills in which 12% of the landfill waste contains used diapers, due to environmental concerns sanitary landfills have been improved and currently there are 21 sanitary landfills.
- Sanitary landfills are equipped with well-designed engineering and management for solid waste disposal and also monitored and operated under compliance control with safety and environmentally friendly measures
- Methane capture systems are installed in the sanitary landfills, it's used for electricity generation. In Bukit Tagar sanitary landfill in Malaysia, the final by-products produce 4 MW of electricity.The capacity of this landfill is 120 million tonnes and can support the disposal needs for the next 65 years

Chapter 3

Guidelines by CPCB

CPCB has provided 6 disposal pathways for sanitary waste, detailed information regarding the technology has been provided below

3.1 Locally made Incinerators

- Can be used for Napkins and other waste, should not be used for pads that have high cellulose content and Super Absorbent Polymers
- To be installed in schools, colleges, hostels, etc.
- It can be Manually operated with a capacity of 200 napkins/day. It will contain two chambers also emission control system should be installed. It can be made out of brick masonry.
- Operational temperature is around 300^0C, it's preferrable to go for low Sulphur diesel, emission coming out of the incinerator should be odorless and free from mist and fume

3.2 Electric Incinerators

- Can be used for huge quantity of Napkin wastes, it can be installed in Community toilets, Malls, Girls Toilets, etc.
- It ensures instant disposal in scientific and hygienic way, fully automated, capacity to incinerate 150-200 Napkins/Day
- Ash generation should not be greater than 5% per napkin, ash has to be collected in separate tray, thermal cut-off, automatic temperature controller and other safety features have to be installed along with the system
- Emission from incinerator has to comply the General Emission Standard mentioned under Standard for incineration in SWM rules 2016.

3.3 High Temperature Incinerators for Bio-Medical Waste

- It has the Capacity to incinerate all types of pads, even with those containing high cellulose content, moisture content and Super Absorbent Polymers.
- It should be installed in Combined incinerator Facility.
- It is capable of taking in feed at 50Kg/hr, it won't be allowed to operate if it doesn't contain the Air pollution Control Device.
- Designed based on Controlled-air incineration principle, PM concentration will be low in these incinerators. Emission has to strictly comply with Schedule II of Bio-Medical Waste Management Rules of 2016, structural details of the incinerator also provided in Guidelines for Bio-Medical Waste Incinerator, 2017.

3.4 Deep Burial

- This method can be used for compostable sanitary pads. It is not recommended for the pads made of bleached cellulose, SAP, and plastic covering.
- It is highly implemented in rural areas and small towns
- In this method, a pit of depth not less than 1 m is constructed and the sanitary items are kept in it.
- The waste should be covered with soil or sand to avoid exposure to open-air

3.5 Composting

- Sanitary waste made of wood pulp and non-woven cotton is suitable for composting. Commercial disposable pads will not compost.
- It can be practiced in both rural and urban communities.
- Used menstrual absorbent should be mixed and covered with materials such as leaves, dried plants, or other bio-degradable material in an earthen pit. Optimum moisture should ensure all through the process.
- Once the pit is filled, it should be covered properly with soil to avoid the smell, destruction from rodents, etc.

3.6 Pit Burning

- It is a suitable method for plain cotton clothes of degradable sanitary material.
- This should be the least preferred option in a rural setting.

- The burning should be carried out at about 1 m depth with some good burning material like dried wood or sometimes kerosene oil or fuel is used.

CPCB has published guidelines for management of sanitary waste, report contains information on safe and unsafe disposal practices

Unsafe	***Common practices***
	Throw them unwrapped into fields, rooftops, etc.
	Wrap them in paper/ plastic bag and throwing them outside
	Drying, wrap in paper/plastic bag and throw in dustbins (mostly non-rural)
	Burry them for de-composting
	Throw them in latrine / toilets
	Burn it (rural areas and peri-urban areas)
	Use small scale incinerators (community or school level)
Safe	Municipal waste management / burning in health clinics (more urban)

Figure 3.1: MHM Guidelines 2015 for disposal

Chapter 4

Startups and Initiatives in Sanitray waste management

4.1 Breaking down sanitary pads without burning

It has been established before that sanitary napkin take 500-800 years to decompose, during the combustion it releases dioxin, phuron and other carcinogenic substances. Pune based Startup Pad Care Labs has come up with collection and disposal system called **SaniBin, SanEco**, through these systems sanitary pads can be converted to **plastic pellets and cellulose** which can be raw materials for paper and plastic industry. Brief groundwork was carried out by the founders to understand the underlying issues, from the data collected they designed a system that caters to everyone who is part of the problem. Sanitary pads discarded are collected in SaniBin which are placed in toilet cubicles. They have an **in-built disinfection system**, prevents the generation of bad odor, these are fed into SanEco, mechanical shredders work on it to disintegrate napkins into smaller bits. Shredded pieces undergo **Disinfection, Decolorization, Deodorization** process before it is finally deactivated. **Sodium Polycarbonate** is added to deactivate the super adsorbent polymers. Output from the system is cellulose and plastic pellets. Blood and other bodily fluids are also broken down in a similar process and sent out as sewage, tests were carried out for pollutants in the sewage, it was found to be within the prescribed limits, so it was adjudged safe to be disposed in Municipal waste water stream.Pad Care vision encompasses **5 SDG Goals** (Good Health, Gender Equality, Clean water and sanitation, Sustainable Cities and Communities and Climate action).

4.2 Sparkle-Biodegradable Sanitary Pads

This Startup envisions to produce sanitary products that are natural, affordable, gentle to the skin and kind to the planet. One aspect which **distinguishes sparkle from other products is their transparency**, they have mentioned about every ingredient that goes into making this product. Primary ingredient which goes into the manufacturing is **Banana Fibre**, it's a **naturally abundant super adsorbent** which is effective in locking away menstrual fluid. It also requires six times less water and ten times less fertilizer. Top layer of the pad is made of **Bamboo Fibre**, which is **naturally anti-bacterial, odor resistant and super soft**. Conventional pads use polypropylene plastic sheet as top layer, which is harmful for the environment. Bamboo is a self-replenishing resource and does not require toxic pesticides or fungicides. **Corn Starch** based bio fuel is used as bottom layer, it is biodegradable and sustainable.

4.3 Red Dot Campaign

SWaCH (Solid Waste Collection and Handling) in cooperation with Rotary club of Pune, launched a Red-Dot Campaign to help waste pickers **avert health hazards during the handling of sanitary waste**. The idea of the campaign is simple: the waste workers ask the households to segregate and **mark their sanitary waste packets/papers bags with a visible red dot** so that they know that it is sanitary waste and that it has to be treated differently. The waste is then sent to a waste-to-energy plant. Pune story teaches us another lesson, Incinerator plants were set up by Pune Corporation for disposal of sanitary waste but could not get traction because they did not consistently receive sorted waste. We possess technology that could get rid of wastes, but it all boils down to how well we segregate and manage waste. Policy making forms an integral part of successful solid waste management practices, we are far behind in making policies that create impact. Small steps that are relevant to the current situation can make a difference.

4.4 Reusable sanitary pads-Sanfe

IIT Delhi Incubated startup, envisions to design and develop products for improving female health and hygiene. They have launched reusable sanitary pad made out of **banana fibre** that can last up to two years (around 120 washes). They are ultra-thin and are highly adsorbent with **Quadrant true Lock technology**, which makes the pad leak proof and avoids creating any rashes. Various ingredients involved in the production of reusable sanitary pads are – Polyester pilling, Terry and Banana fibre, Cotton Polyurethane Laminate.

4.5 Green Dispo

Scientists from International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad in collaboration with NEERI and Sowbal Aerothermics developed an eco-friendly high temperature sanitary napkin incinerator called **Green Dispo**. It instantly heats up to temperatures greater than 800^oC, which helps in complete combustion of sanitary pad wastes with **minimum flue gas emissions**.

4.6 Review on Incinerator performance by Researchers from Indian Institute of Science

Many companies have introduced incinerators into the market, a careful evaluation is required before choosing the most environmentally friendly product.

- Two commercially available incinerators were considered for the study, parameters taken for comparison were combustion efficiency and emissions (CO, CO2), Incinerator models that are studied, have already been installed in many schools and colleges all over the country.

- Both incinerators have single chamber with batch type operation, both can accommodate 5 napkins at a time. Water was used to simulate the effect of menstrual blood in the sanitary napkins.

- Products of the combustion were analyzed by drawing a sample at 2 LPM to gas analyzer, electrochemical sensors were used to monitor SO_x, NO_x, CO and O2. Emission and temperature data were collected from the instant the batch was loaded till the material has been combusted leaving behind incombustible ash.

- CPCB has set standards for combustion efficiency, half hourly average CO concentrations, formulas provided in CPCB Manual

- Ultimate analysis was carried out to find COHNS composition of sanitary napkin, hence stoichiometrically air required for combustion was calculated. X-Ray diffraction study was carried out on the ash collected, predominantly it contained titanium oxide and heavy metals were absent.

- From the emission and temperature data collected it was concluded that both incinerators fall short in meeting the CPCB standards, they seem to perform well when the batch size is small, it's specified by the manufacturer that it can burn 5 sanitary napkins at a time, but the results are poor. Air flow through the chamber due to natural draught was found to be insufficient and there's a need for external air supply
- Electric resistance heating rates are low in the chamber, and a considerable amount energy is expended on heating the chamber mass itself. There is no provision of injection of air over and under the waste bed, and the combustion chambers were poorly designed. To overcome this issue LPG can be used. This method ensured quick heating to high temperatures wherein the LPG flame was made to focus on the desired waste bed region, thereby ensuring effective utilization of the heat supplied

4.7 Alternatives

- Apart from wood pulp used in both disposable diapers and sanitary napkins, **chlorine bleach** is a key ingredient; used to whiten the pulp for aesthetic reasons. Chlorine bleach is both an environmental and health hazard, releasing toxic chemicals as a by-product of the bleaching process.
- **Re-usable Modern Cloth Diapers (MCD)** have two parts, a water-tight outer cover with a washable cloth insert inside. Once the MCD is full, the poop is flushed down the toilet, the inserts washed and re-used. Further, the baby does not come in contact with a harmful cocktail of chemicals found in any disposable diaper
- MCDs also work out to be more economical if used over a two year period compared to disposable diapers not to mention their enormous positive impact on the environment.
- Options exist for concerned women who want to explore healthier and more environmentally sustainable options for sanitary napkins. **"SheCup"** which is worn internally, and is made from silicone and designed like a cup to collect the menstrual blood. This can be worn for 12 hours. Once full, the contents of the cup can simply be emptied into the toilet, and the cup can be cleaned and worn again
- Second option is a **re-usable sanitary napkin** made from cloth. The design and use of these cloth napkins is similar to disposables, and they provide absorbency by using many layers of cotton. They have **options for heavy and light flow days** and a combination of the two can fully substitute disposable napkins every month.
- The thought of switching entirely to reusable options may seem daunting. But every sanitary napkin or disposable diaper you can save from a landfill will have a cascading effect and positively impact forests, water, air, the city you live in and your health

Chapter 5

Challenges in Sanitary waste Management

5.1 Point of Disposal

Appropriate disposal of used menstrual material is still lacking in many countries of the world. Most of the countries have developed techniques to manage their fecal and urinary wastes but, because of lack of menstrual management practices in the world, most of the women dispose of their sanitary pads or other menstrual articles into domestic solid wastes or garbage bins that ultimately become a part of solid wastes. Toilet facilities in India **lack bins for the disposal of sanitary pads**. In urban areas, where modern disposable menstrual products are used, they dispose of them by **flushing in toilets and throwing in dustbins** or through solid waste management, but, in rural areas, there are many options for disposing of menstrual waste such as by burying, burning, and throwing in the garbage or pit latrines. **In rural areas, most women use reusable and non-commercial sanitary materials like reusable pads or cloths**. Thus, they generate a lesser amount of menstrual waste as compared to women in urban areas who rely on commercial disposable pads.

5.2 Social Conflict and Disposal Myths

The menstrual material was disposed of according to the type of **product used, cultural beliefs, and location of disposal**. In slum areas, women dispose of their menstrual waste into pit latrines as burning and burial were difficult due to limited private space. The reason behind that is it was seen by men or used in witchcraft. In some places, people **believe that burning menstrual waste would induce infertility in menstruating women**. That is why even in urban areas many girls are reluctant to use incinerators installed in colleges and hostels. In some schools, incinerators or "feminine hygiene bins" are used for disposing of menstrual waste material but due to shyness or fear of being seen by others, they refrained from using it.

The **behavior of women regarding disposal is different when being at home and away from home**. At home, they dispose of the waste by wrapping and throwing it in the dustbin along with other domestic waste. As mentioned above, the disposing habits change according to the place. In public places, before knowing the consequences of flushing the pads, they flush them in the toilets or wrap and throw them in the dustbins. In many cities, the persons who manage the public toilets always complain of blockage of sewage system because of flushing of sanitary pads or rags in the toilet

5.3 Segregation and Collection

Sanitary waste should be treated as a **separate stream** and should not end up in a dry or wet trash bin as a best practice of collection and segregation. It should be placed in a brown paper bag or newspaper with a red dot on it and given to the garbage collector as a separate waste stream. However, there are numerous obstacles to overcome. To begin with, there is a **social stigma**; in many communities, women are too embarrassed to separate their sanitary waste and offer it to the garbage collection. If they do, the garbage collector will refuse to accept it due to the absence of guidelines and the **taboo nature of the product**. And if he does, it will be mixed up with other waste streams. In this manner at the later stage, the waste is **segregated manually by the waste pickers**. This exposes them to micro-organisms like E. Coli, salmonella, staphylococcus and pathogens that are responsible for life-threatening diseases like **hepatitis and tetanus**.

Gloves and proper safety tools should be provided to the cleaners, which will need a separate **hygiene budget plan**. Then after segregation, the sanitary waste is driven out of the city and buried in a landfill. Since it is non-biodegradable waste, this ends up staying in landfills for up to 800 years. **Deodorized sanitary products** used by women/girls contain chemicals used in bleaching such as **organochlorines** which when buried in the soil disturb the soil microflora and decomposition takes time. The result – overflowing landfills causing endless harm to the environment

5.4 Technology

Although incineration is a superior method of disposing of menstruation waste, burning pads emit toxic gases that are damaging to both health and the environment. When inorganic materials are burned at low temperatures, dioxins are released, which are poisonous and carcinogenic. Many people have complained about odor problems. As a result, a **high temperature is required to alleviate the current condition. However, the economics will be thrown off**.

Composting also has several drawbacks. **Germs and harmful bacteria thrived in these materials**, which were saturated in blood and faeces. These could carry hepatitis and HIV viruses, which can survive in the soil for up to six months and keep their infectivity. Therefore, liner material has to be adopted before composting or just dumping it into a pit. Which will increase the cost of dumping

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WHAT IS LCA?

In the Society of Environmental Toxicology and Chemistry (SETAC) LCA is defined as an objective process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and material uses and releases to the environment, and to evaluate and implement opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activities, encompassing extracting and processing materials; manufacturing, transporting and distribution; use, reuse, maintenance; recycling and final disposal. Another definition for LCA can be found in ISO14040 which describes LCA as a technique for assessing the environmental aspects and potential impacts associated with a product by: compiling an inventory of relevant inputs and outputs of a product system, evaluating the potential environmental impacts associated with those inputs and outputs and interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.

VARIANTS OF LCA

Cradle-to-grave

The whole Life Cycle Assessment, from resource extraction ('cradle') to use and disposal ('grave'), is known as cradle-to-grave. For example, from procuring raw materials for sanitary napkins through ensuring that each raw item is properly disposed away. For all phases of the life cycle, all inputs and outputs are considered.

Cradle-to-gate

It's a review of a portion of a product's life cycle, from resource extraction to factory gate. (i.e., before it is transported to the consumer). In this situation, the product's usage and disposal phases are ignored. Environmental product declarations (EPDs) known as business-to-business EPDs are sometimes based on cradle-to-gate analyses. The life cycle inventory (LCI) is one of the important applications of the cradle-to-gate concept. This enables the LCA to capture all impacts prior to the facility purchasing resources. They can then add the stages in their transport to plant and manufacturing processes to establish their own cradle-to-gate values for their product more readily.

Cradle-to-cradle or closed loop production

Cradle-to-cradle is a type of cradle-to-grave evaluation in which the product's end-of-life disposal step is a recycling procedure. It's a way for reducing a product's environmental impact by using sustainable manufacture, operation, and disposal procedures, as well as incorporating social responsibility into product development. New, same items (e.g., using fibres to make a new sanitary pad) or different products are created as a result of the recycling process (e.g., use of fibres as a new filling material in quilt).

Gate-to-gate

A partial LCA that looks at only one value-added step in the entire production chain is known as gate-to-gate. Gate-to-gate modules can also be integrated in their respective manufacturing chains to produce a complete cradle-to-gate assessment.

Ecologically based LCA

While a conventional LCA employs many of the same methods and procedures as an Eco-LCA, the latter takes into account a far larger spectrum of environmental effects. It was created to serve as a guide to smart human activity management by recognising the direct and indirect effects on natural resources and ecosystems. Eco-LCA is a methodology developed by the Ohio State University Centre for Resilience that statistically considers regulating and supporting services during the life cycle of commercial goods and products. Services are divided into four categories under this approach: supporting, regulating, supplying, and cultural services.

STAGES OF LCA

International standards on LCAs (ISO 14040 and ISO 14044) divide LCAs into four main stages:

- **Goal and scope definition:** Objective (goal) and the methodological approach (scope).

- **Inventory analysis:** For each of the unit operations that make up the product's life cycle, all raw materials and emissions (inputs and outputs) are taken into account. Natural resources, such as land and water, as well as produced commodities, such as fuels and chemicals, are all inputs. All goods and by-products, as well as all outputs, are released into the air, water, and land. These unit processes, when combined, make up the life cycle system to be studied, which is defined by the product system boundary. The Life Cycle Inventory (LCI) is a comprehensive list of resources and emissions that is updated on a regular basis (inputs and outputs).

- **Impact assessment:** Assesses the life cycle inventory by tying resources and emissions to their environmental and human health consequences. In this method, the inputs and outputs are grouped into common areas of environmental concern, such as human health impacts, ecosystem impacts, and so on. This can be done to differing degrees of complexity, and a variety of Life Cycle Impact Assessment (LCIA) approaches have been created to evaluate a product system's possible environmental implications.

- **Interpretation:** A systematic technique for identifying, quantifying, checking, and evaluating information from the results of a life cycle inventory and/or a life cycle impact assessment is known as life cycle interpretation. During the interpretation phase, the results of the inventory analysis and impact assessment are summarised. The interpretation process culminates in a set of study conclusions and suggestions. The following should be included in the interpretation, according to ISO 14043:
    - Identification of significant issues based on the results of the LCI and LCIA phases of an LCA
    - Evaluation of the study considering completeness, sensitivity and consistency checks
    - Conclusions, limitations and recommendations

In the current study Sanitary Pads is taken for LCA Study. First step in LCA is to define the Goal and scope of the study.

Goal and scope:

Model the various processes involved in the production, use and disposal of sanitary napkins. Estimating the impacts such as Greenhouse warming potential, Acidification Potential, Eutrophication Potential, Human Health Particulate Air and Smog Air.

Functional Unit:

The reference stream is calculated for 13 4-day menstrual cycle per year. It is assumed that 4 pads are used every day, to ensure menstrual protection for 50 women over a one-year period. Totally it amounts to 10400 sanitary pads.

Components in Sanitary Pad:

Component	Percentage
Fluff Pulp	48
LDPE	36
Adhesives	7
Super Absorbent Polymer	6
Paper	3

Weight of one Sanitary Pad = 13.5g

Total Weight of Fluff pulp = 67.392 kg (10400*0.0135*0.48)
Total Weight of LDPE = 50.544 kg (10400*0.0135*0.36)
Total Weight of Adhesives = 9.828 kg (10400*0.0135*0.07)
Total Weight of Super Absorbent Polymer = 8.424 kg (10400*0.0135*0.06)
Total Weight of Paper = 4.212 kg (10400*0.0135*0.03)
Data was obtained from Ecoinvent version 3.8 (2021) Database and LCA was performed using GaBi software.
It was assumed that Sanitary napkins are produced in Ranga Reddy district of Telangana and transported to Chennai via diesel train.
It’s assumed that used sanitary napkins are sent directly to landfill.

Limitations of the Study:

Data for Fluff pulp was not available in Ecoinvent database, so a similar material (cellulose) was taken.
While providing the inflow and outflow for various components, few inflow and outflow components which has a very less contribution and not applicable to the study was not considered.
Only 6 impact parameters were considered for the study.
Data on few parameters were very scarce so it was taken after reading many research papers.

Input and output for all the components in LCA:

Inputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Electricity [Electric power]	**Energy (net ca**	**413**	**MJ**	**X**	**0 %**	**(No statement)**
Ethylenediaminetetraacetic acid	**Mass**	**0.168**	**kg**	**X**	**0 %**	**(No statement)**
Hydrogen peroxide (50%) [Inor	**Mass**	**1.01**	**kg**	**X**	**0 %**	**(No statement)**
Softwood lumber [Materials fron	**Volume**	**0.153**	**m3**	**X**	**0 %**	**(No statement)**
Water (cooling water) [Operatin	**Mass**	**637**	**kg**	**X**	**0 %**	**(No statement)**
CH: petrol, unleaded, at refinery [fue	Mass	30.4	kg		0 %	(No statement)
Sodium silicates [Inorganic emissions t	Mass	1.35	kg		0 %	(No statement)

Fig 1: Cellulose Input

Outputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Cellulose (fibres) [Organic interr	**Mass**	**67.4**	**kg**	**X**	**0 %**	**(No statement)**
Hazardous waste (underground depos	Mass	0.00244	kg	*	0 %	(No statement)
Hazardous waste for incineration [Haz	Mass	0.0354	kg	*	0 %	(No statement)
Municipal solid waste deposition [Cons	Mass	0.0384	kg	*	0 %	(No statement)
Product waste (plastics) [Consumer w	Mass	0.015	kg	*	0 %	(No statement)
Biological oxygen demand (BOD) [Ana	Mass	0.01	kg		0 %	(No statement)
Carbon dioxide, fossil [ecoinvent long	Mass	99.4	kg		0 %	(No statement)
Carbon dioxide, non-fossil [ecoinvent	Mass	0.02	kg		0 %	(No statement)
CH: disposal, wood ash mixture, pure,	Mass	0.152	kg		0 %	(No statement)
Chemical oxygen demand (COD) [Ana	Mass	0.0318	kg		0 %	(No statement)
DOC, Dissolved Organic Carbon [Anal	Mass	0.00937	kg		0 %	(No statement)
Nitrogen oxides [Inorganic emissions t	Mass	0.000155	kg		0 %	(No statement)
Nitrogen oxides [ecoinvent long-term	Mass	0.0324	kg		0 %	(No statement)
Waste water [Other emissions to fresl	Mass	1.32E003	kg		0 %	(No statement)

Fig 2: Cellulose Output

Inputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
RER: butyl acrylate, at plant [organics	Mass	0.727	kg		0 %	(No statement)
RER: esters of versatic acid, at plant	Mass	1.23	kg		0 %	(No statement)
RER: vinyl acetate, at plant [monomer	Mass	2.65	kg		0 %	(No statement)
Water, unspecified natural origin [Wa	Volume	0.00452	m3		0 %	(No statement)
Flows						

Fig 3: Adhesive Input

Outputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Acrylic sealing compound [Plasti	**Mass**	**9.83**	**kg**	**X**	**0 %**	**(No statement)**
Biological oxygen demand (BOD) [Ana	Mass	0.000176	kg		0 %	(No statement)
COD, Chemical Oxygen Demand [ecoi	Mass	0.00167	kg		0 %	(No statement)
Dissolved solids [ecoinvent long-term	Mass	0.00353	kg		0 %	(No statement)
Water [Water]	Mass	3.84	kg		0 %	(No statement)

Fig 4: Adhesive Output

Inputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Compressed air 6 bar [Mechanic	**Standard volu**	**1.45**	**Nm3**	**X**	**0 %**	**(No statement)**
Electricity [Electric power]	**Energy (net ca**	**173**	**MJ**	**X**	**0 %**	**(No statement)**
Ethene (ethylene) [Organic inte	**Mass**	**50.5**	**kg**	**X**	**0 %**	**(No statement)**
CH: petrol, unleaded, at refinery [fue	Mass	12.8	kg		0 %	(No statement)
Water (feed water) [Water]	Mass	2.36E003	kg		0 %	(No statement)

Fig 5: LDPE Input

Outputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Polyethylene low density compo	**Mass**	**50.5**	**kg**	**X**	**0 %**	**(No statement)**
Hazardous waste for incineration [Haz	Mass	0.089	kg	*	0 %	(No statement)
Product waste (plastics) [Consumer w	Mass	0.12	kg	*	0 %	(No statement)
Water (waste water, untreated) [Proc	Mass	97	kg	*	0 %	(No statement)
Biological oxygen demand (BOD) [Ana	Mass	0.000409	kg		0 %	(No statement)
Carbon dioxide, fossil [ecoinvent long	Mass	42.8	kg		0 %	(No statement)
COD, Chemical Oxygen Demand [ecoi	Mass	0.00272	kg		0 %	(No statement)
Dust (PM10) [Particles to air]	Mass	0.000166	kg		0 %	(No statement)
Dust (PM2.5) [Particles to air]	Mass	4.69E-006	kg		0 %	(No statement)
Nitrogen oxides [ecoinvent long-term	Mass	0.0136	kg		0 %	(No statement)
NMVOC, non-methane volatile organic	Mass	0.052	kg		0 %	(No statement)

Fig 6: LDPE Output

Inputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Aluminium sulfate [Inorganic int	**Mass**	**0.0387**	**kg**	**X**	**0 %**	**(No statement)**
Electricity from hard coal [Syste	**Energy (net ca**	**42.8**	**MJ**	**X**	**0 %**	**(No statement)**
Kaolin (aluminium silicate) [Mine	**Mass**	**0.237**	**kg**	**X**	**0 %**	**(No statement)**
Hard coal India [Hard coal (resource)]	Mass	0.0527	kg		0 %	(No statement)
Water, cooling, unspecified natural or	Volume	0.22	m3		0 %	(No statement)
Water, unspecified natural origin [Wa	Volume	0.0548	m3		0 %	(No statement)
Flows						

Fig 7: Paper Input

Outputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Paper woodfree uncoated (t94)	**Mass**	**4.21**	**kg**	**X**	**0 %**	**(No statement)**
Hazardous waste (underground depo	Mass	0.00143	kg	*	0 %	(No statement)
Municipal solid waste deposition [Cons	Mass	0.00632	kg	*	0 %	(No statement)
Carbon dioxide, fossil [ecoinvent long	Mass	10.5	kg		0 %	(No statement)
Carbon dioxide, non-fossil [ecoinvent	Mass	1.93	kg		0 %	(No statement)
Carbon monoxide, non-fossil [ecoinve	Mass	0.00305	kg		0 %	(No statement)
Nitrogen oxides [ecoinvent long-term	Mass	0.00231	kg		0 %	(No statement)
Sulphur dioxide [ecoinvent long-term	Mass	0.00146	kg		0 %	(No statement)

Fig 8: Paper output

Inputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Electricity [Electric power]	**Energy (net ca**	**12.6**	**MJ**	**X**	**0 %**	**(No statement)**
Nitrogen liquid [Inorganic interm	**Mass**	**0.16**	**kg**	**X**	**0 %**	**(No statement)**
Propene (propylene) [Organic in	**Mass**	**5.31**	**kg**	**X**	**0 %**	**(No statement)**
Cooling water [Waste for recovery]	Mass	19.5	kg	*	0 %	(No statement)
CH: petrol, unleaded, at refinery [fue	Mass	0.928	kg		0 %	(No statement)
Oxygen [Renewable resources]	Mass	6.06	kg		0 %	(No statement)
Water [Water]	Mass	0.219	kg		0 %	(No statement)
Water (ground water) [Water]	Mass	6.99	kg		0 %	(No statement)
Water, cooling, unspecified natural or	Mass	138	kg		0 %	(No statement)

Fig 9: SAP input

Outputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Acrylic acid [Organic intermedia	**Mass**	**8.42**	**kg**	**X**	**0 %**	**(No statement)**
Hazardous waste for incineration [Haz	Mass	0.00108	kg	*	0 %	(No statement)
Biological oxygen demand (BOD) [Ana	Mass	0.00251	kg		0 %	(No statement)
Carbon dioxide, fossil [ecoinvent long	Mass	3.04	kg		0 %	(No statement)
Chemical oxygen demand (COD) [Ana	Mass	0.00268	kg		0 %	(No statement)
Nitrogen [Renewable resources]	Mass	0.16	kg		0 %	(No statement)
Nitrogen oxides [Inorganic emissions t	Mass	0.000991	kg		0 %	(No statement)
TOC, Total Organic Carbon [ecoinvent	Mass	0.000969	kg		0 %	(No statement)
Water [Water]	Mass	141	kg		0 %	(No statement)

Fig 10: SAP Output

Inputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Acrylic acid [Organic intermedia	**Mass**	**8.42**	**kg**	**X**	**0 %**	**(No statement)**
Acrylic sealing compound [Plasti	**Mass**	**9.83**	**kg**	**X**	**0 %**	**(No statement)**
Cellulose (fibres) [Organic interm	**Mass**	**67.4**	**kg**	**X**	**0 %**	**(No statement)**
Electricity [Electric power]	**Energy (net ca**	**308**	**MJ**	**X**	**0 %**	**(No statement)**
Paper woodfree uncoated (t94)	**Mass**	**4.21**	**kg**	**X**	**0 %**	**(No statement)**
Polyethylene low density compo	**Mass**	**50.5**	**kg**	**X**	**0 %**	**(No statement)**
CH: petrol, unleaded, at refinery [fue	Mass	22.7	kg		0 %	(No statement)
Water, cooling, unspecified natural or	Volume	0.475	m3		0 %	(No statement)

Fig 11: Assembly Input

Outputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Sanitary ware [Other home appl	**Mass**	**140**	**kg**	**X**	**0 %**	**(No statement)**
Hazardous waste (underground depos	Mass	0.00182	kg	*	0 %	(No statement)
Hazardous waste for incineration [Haz	Mass	0.0264	kg	*	0 %	(No statement)
Water (waste water, untreated) [Proc	Mass	451	kg	*	0 %	(No statement)
Biological oxygen demand (BOD) [Ana	Mass	0.000727	kg		0 %	(No statement)
Carbon dioxide, fossil [ecoinvent long	Mass	74.1	kg		0 %	(No statement)
Carbon dioxide, non-fossil [ecoinvent	Mass	0.0149	kg		0 %	(No statement)
COD, Chemical Oxygen Demand [ecoi	Mass	0.00483	kg		0 %	(No statement)
Nitrogen oxides [ecoinvent long-term	Mass	0.0242	kg		0 %	(No statement)

Fig 12: Assembly Output

Inputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Sanitary ware [Other home appl	**Mass**	**140**	**kg**	**X**	**0 %**	**(No statement)**
CH: diesel, low-sulphur, at refinery [fi	Mass	0.878	kg		0 %	(No statement)
Flows						

Fig 13: Transport Input

Outputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin
Sanitary ware [Other home appl	**Mass**	**140**	**kg**	**X**	**0 %**	**(No statement)**
Carbon dioxide, fossil [ecoinvent long-	Mass	0.349	kg		0 %	(No statement)
Carbon monoxide, fossil [ecoinvent lo	Mass	7.41E-005	kg		0 %	(No statement)
Nitrogen oxides [ecoinvent long-term	Mass	0.000274	kg		0 %	(No statement)
Flows						

Fig 14: Transport Output

Inputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin	C
Sanitary ware [Other home appl	**Mass**	**140**	**kg**	**X**	**0 %**	**(No statement)**	
Flows							

Outputs

Flows	Quantities	Amount	Units	Tra	Standar	Origin	C
Landfill of textiles [Consumer waste]	Mass	140	kg	*	0 %	(No statement)	
Flows							

Fig 15: Landfill Input and Output

Flowchart of the entire production of Sanitary Pads

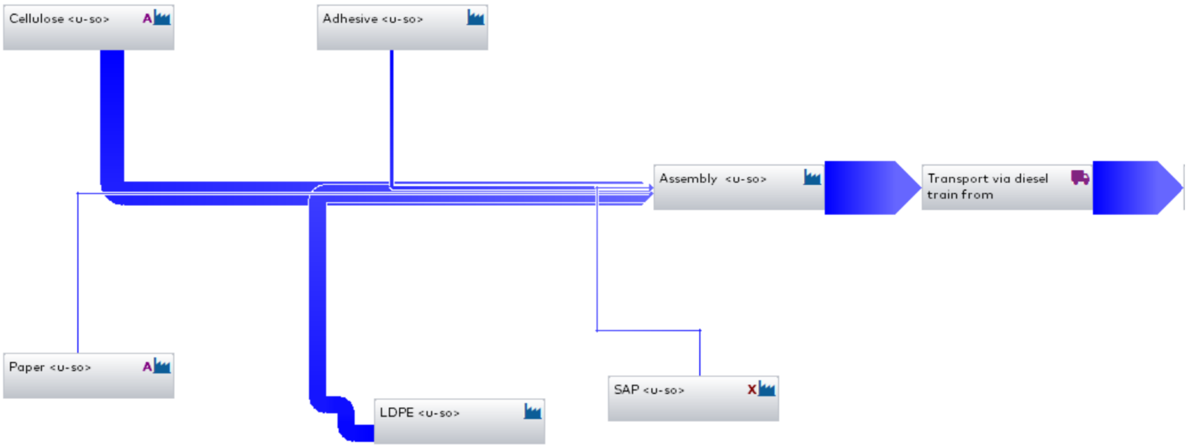

Fig 16: Flowchart

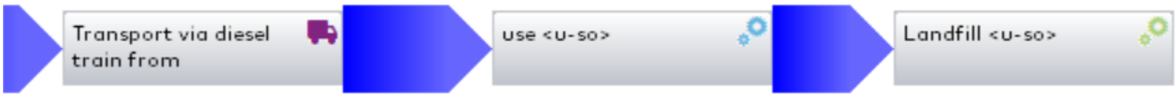

Fig 17: Flowchart after transport stage

Impact Results:

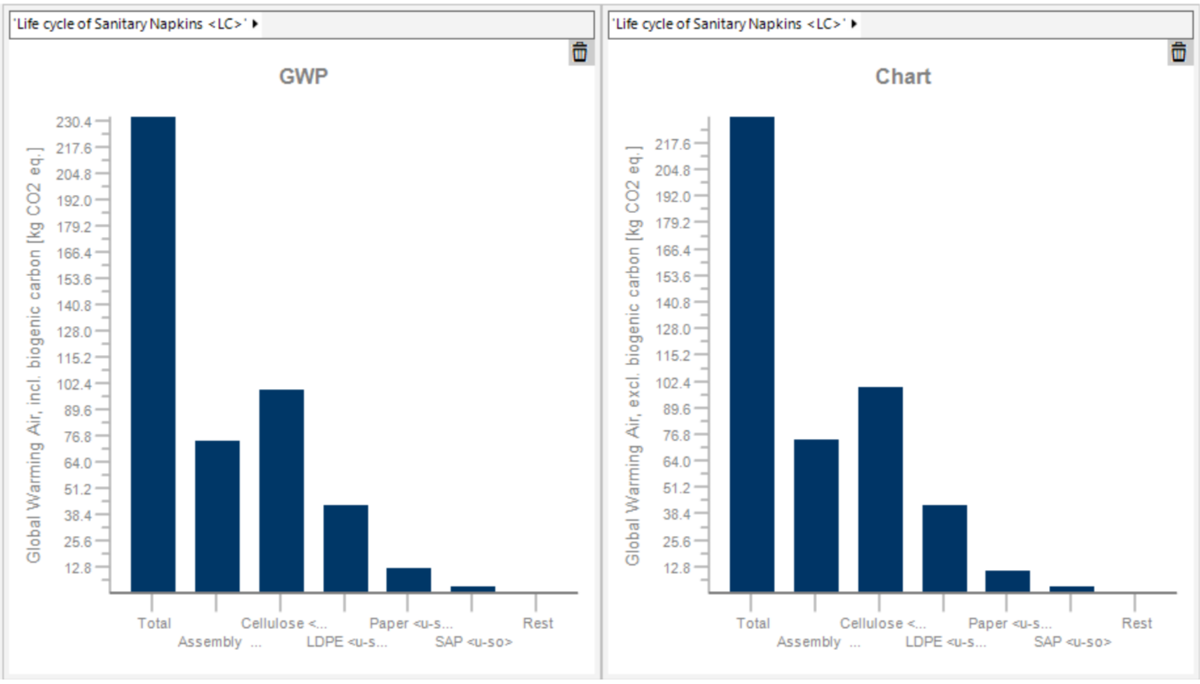

Fig 18: Global Warming Potential

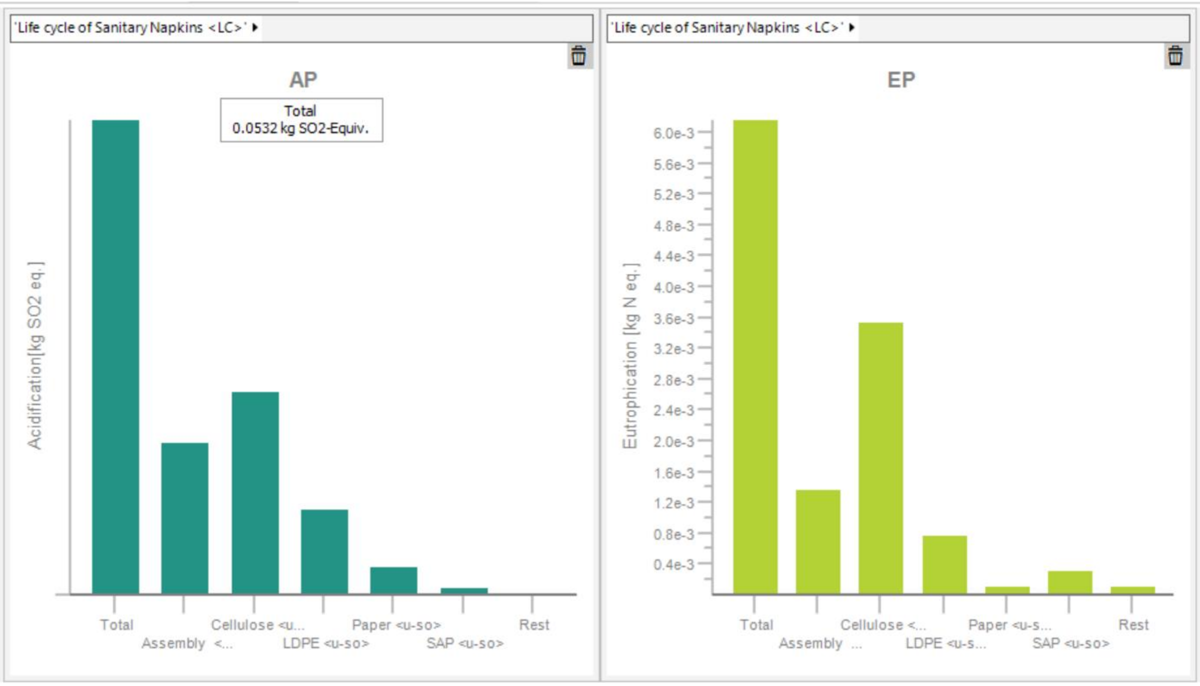

Fig 19: Acidification and Eutrophication Potential

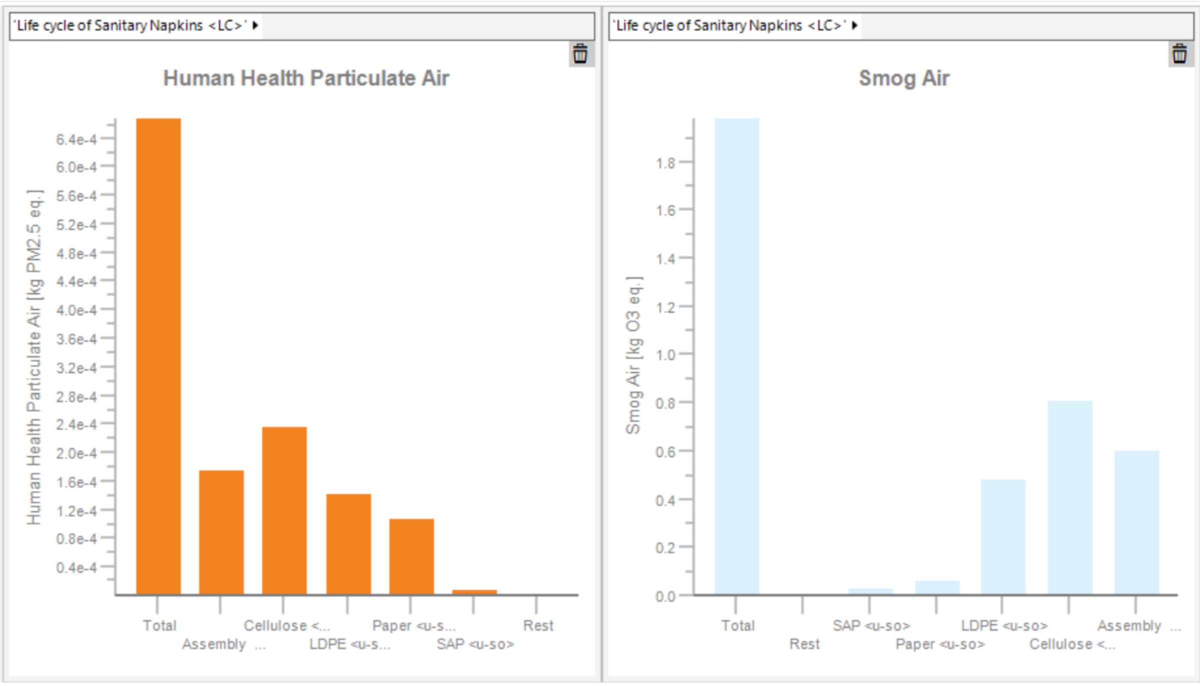

Fig 20: Human Health Particulate Air and Smog Air

Results:

Most important parameter is the GWP of Sanitary pads; GWP turns out to be 230.4 kg CO_2 eq for 10400 sanitary pads.

In order to find the GWP of sanitary pads used by one individual.

Total No. of sanitary pads used by an individual in a year is: 208 (13*4 (13 4-day menstrual cycle) * 4(No. of times pads are changed per day))

CGWP = 4.608 kg CO_2 eq (230.4*(208/10400))

From research papers it was found out that actual GWP of sanitary pads was around 5.2 kg CO_2 eq

From the results posted above, it can be concluded that cellulose production is the major contributor for all the impacts listed above. Assembly stage also has a significant impact. Transport could have played a huge role if the products were airlifted. From the results, the producer could try to optimise his assembly process or look out for alternatives of cellulose which is less energy consuming and less polluting. If renewable sources are adopted in the manufacturing of cellulose, then it could also reduce GWP and other impacts, I have considered that electricity is produced from fossil fuels.