Proceedings of the International Conference on Industrial Engineering and Operations Management
Manila, Philippines, March 7-9, 2023

Sustainable Operations in Paper and Pulp Industry: Analysis of Challenges

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Abstract

A paper making process adopts primarily a generic flow of steps across industries. This industry is one of the largest in the world and is touted to be growing further with incremental demand for paper and its affiliated products for its eco-friendliness. However, paper and pulp industry is a heavily resource dependent industry be it forest resource, water resource, energy or chemicals. In fact, it is said to be one of the top five leading consumers of energy. Given such, this industry is a major contributor to depleting natural resources and increasing greenhouse gas emission, adding intensively to the global warming. Against such a backdrop, it offers relevant cause to study the scholarly discussion and debate on sustainable issues in paper and pulp industry playing around the academic universe and also to poke into and discuss some of the issues of sustainability in the industry emerging out of the articles. Accordingly, through this article, the present state of affairs in the academic fraternity on the above topic has been laid out through a bibliometric analysis, while some of the common challenges of environmental sustainability associated with the paper making process have been identified from the literature and discussed thereof.

Keywords
Paper, Pulp, Sustainable, Challenge, Resources

1. Introduction

The history of 'Paper' is attributed to 3700 BC ago to its Greek origin from the word 'Papyrus', derived from its formation out the stalks of a papyrus plant used as a surface or base for writing (Chauhan and Meena 2021). The process of wood-based paper making starts from debarking and scrubbing of wood (Corcelli et al. 2018). The debarked and scrubbed wood is then chipped into smaller chunks of defined range, a process called chipping. The chipped woods are then sent to digesters where it is mixed with chemicals and given steam-bath to dissolve lignin and decouple the cellulose (Corcelli et al. 2018). The resultant product is the cooked pulp and the byproduct is a waste called black liquor. The cooked pulp is further washed, screened and refined to remove any residual fiber, chemical and impurities. Thereafter the material goes through a bleaching process to remove residual lignin. The bleached pulp is then sent to final paper production stage, where it goes through multiple processes and ultimately emerges out as paper sheet. In the last stage, coating and finishing operations are carried out to produce the material in its consumable form (Corcelli et al. 2018).

Being one of the largest industries in the world, the pulp and paper industry is increasingly contributing to the growth of world economy with continents such as North America (38%), Europe (27%) and Asia (18%) being the major players (Baffani 2018; Chauhan and Meena 2021). Global production of paper has exceeded more than 400 MMT with China, USA and Japan consuming more than 50% of the production (Haggith 2018). According to Haggith (2018), the global average of per capita consumption of paper is 55 Kg annually, with maximum consumption in the North American region, the per capita figure being 215 Kg annually. According to IEA (2009), the demand or world paper and paperboard is expected to increase with annual production expected to touch a figure between 700 – 900 MT by 2050. China, India and other developing countries of Asia are predicted to be the major contributing players to this growth (Kong et al.2016; Chauhan and Meena 2021). As of 2020, there are nearly 5000 pulp and paper mills around the world (Vaez and Zilouei 2020). Primary demand for Paper and pulp industry is as writing and reading materials, but also has demand for other applications such as packaging, decoration, graphics, signage, cleaning etc. In fact, the demand for packaging accounts for more than 55% of global paper consumption (Chauhan and Meena 2021). Post Pandemic, due to growing preference and compatibility with digital technology, the pattern of demand is shifting towards paper as a packaging product. Even with the introduction of environmental regulations over ban on non-bio degradable items such as polyethene's, is also expected to account for increasing demand for their paper substitutes.

However, paper and pulp making process is highly unsustainable, capable of disrupting the environmental fabric of the society. Major threats emerging out of a paper making business are deforestation, hazardous chemical effluents, heavy fuel consumption etc., all contributing to proliferation of carbon dioxide and other GHGs. Wood is a major raw material for paper industry (Kulkarni 2013). Deforestation is one of the most direct and obvious source of carbon gas emission. Most of the GHG emitted from paper and pulp industry is CO^2 (Jauhar et al. 2015). Atmospheric emission of CO_2 and chloroform, comprising of the major greenhouse gases, is a prime contributor to global warming (Setthasakko 2010). In order to counter the increasing threat of global warming, reduction in industrial usage of energy is most essential as human use of fossil fuel is a significant contributor to the global warming (IPCC 2014). Being energy efficient is the primary solution in the present scenario to arrest global CO_2 emission (Cullen and Allwood 2010; Carrillo-Hermosilla et al. 2009; Ragsdell 2000). It is predicted that about half of the cumulative emission reductions, required to meet the 2ºC target, can be met by improving energy-efficiency (IEA 2011). Other essential natural resources exploited extensively in a paper production process are energy and water, primarily for steam generation and electricity production (Setthasakko 2010). Paper and pulp industry is world's fifth-leading consumer of energy (Jauhar et al. 2015). Being a capital and resource-intensive industry, the pulp and paper industry contributes adversely to the environmental sustainability causing greenhouse emission, human toxicity, ecological toxicity, water contamination and others (Blazejczak and Edler 2000; Pineda-Henson et al. 2002).

Taking cognizance of the adverse impact of the pulp and paper making process and sharp scrutiny of the social community and the governments alike, practices of sustainable supply chain to mitigate negative impact caused by unsustainable production systems are finding space (Das 2018; Ghadge et al. 2018; Beckmann et al. 2014; Meckenstock et al. 2016). Being sustainable only in the bottom line is no longer a measure of a firm's image, rather it is measured by its performance towards all-encompassing sustainable activity (Barbosa-Povoa et al. 2018; Zhang and Anjali 2014). With even the supply chain partners becoming aware of the importance of triple bottom line (TBL) performance, it is in the interest of every business unit, irrespective of whether it is a supplier or manufacturer or customer, to ensure that it adheres to some practice of sustainable business operations, if it intends to continue its business growth. So, given the adverse impact that a paper and pulp industry have on the environment and the human sustenance, it becomes very relevant to explore the issues of sustainability in one of the unsustainable industries, i.e., paper and pulp industry, prevailing in the academic world and the society in more depth. This is where the focus of the current article lies.

1.1 Objectives

Accordingly, the research questions this paper pursues to address are:
RQ1. What is the present status of academic discourse on sustainability in paper and pulp industry?
RQ2. What are the challenges of sustainability throughout the paper making process impacting the paper and pulp industry?
Through this paper, the author intends to present the pressing issues of sustainability in the paper and pulp industry, as discussed in the literature, through a bibliometric analysis and highlight some of the pressing challenges which emerge out of the same. The flow of this paper is described thus: Section.2 describes the research methodology adopted for the study and the details of the process followed for literature search and literature selection. Section.3 discusses the data analysis modules adopted for the present study. Section.4 interprets the results out of the bibliometric analysis to make some meaningful inferences, discusses some of the sustainability related challenges concerning ecological issues of the paper making industry emerging out of the existing literature and proposes some improvement areas. Section.5 concludes the present study with some future research directions under "Conclusion".

2. Research Methodology

The first research objective stated for this paper is analysed through a bibliometric study of the prevailing literature on paper and pulp industry to get an outlook on the depth of the academic discourse on sustainable, or rather unsustainable, practices in this industry. Bibliometric tools aid in tracing the evolution of sustainability as well as to identify emerging research focus within the domain of interest (Ertz & Leblanc-Proulx 2018). Through bibliometric analysis, various properties of knowledge domains can be understood with the help of mathematical and statistical outcomes (Mora et al. 2017).It is a scientific method of synthesizing scientific literature to identify new and rich areas in business research (Donthu et al. 2021). The second research objective is to identify the specific challenges of sustainability pertaining to pulp and paper industry. In order to achieve the said objective, content analysis of important and relevant literature on the extant topic was conducted since this technique allows replication and making valid inferences from texts or other meaning matters within any given context (Krippendorff 2004). Bengtsson (2016) says that qualitative content analysis aids in extracting meaningful data from literature and draw

realistic conclusions from it. It enables to bring out insights on topics beyond what quantitative data can provide (Gaur and Kumar 2018). Content analysis along with bibliometrics provides valuable insights into emerging research field (Ayan et al. 2022) and has found application across several studies (Gaur and Kumar 2018).

2.1 Data Collection

In order to collect data for the present study, relevant literature from the database of Scopus and Science Direct were obtained, as Scopus and Science Direct are widely accepted repository of online bibliographic databases (Aria and Cuccurullo 2017). In Scopus, literature search was carried out over two rounds through different criteria to ensure relevant literature situation. In the first round under the search option, the keywords were selected as ((("SUSTAINABLE" OR "SUSTAINABILITY") AND ("PAPER") AND ("PULP") AND "INDUSTRY" AND "WOOD")) within 'TITLE, ABSTRACT, KEYWORDS' limited to document type 'Articles' and within the journals pertaining to the subject area of 'Environmental Science', 'Agricultural and Biological Science', 'Energy', 'Business, Management and Accounting', and 'Earth and Planetary'. In the second round under the search option, the choice of keywords for search were '("sustainable" OR "circular economy" OR "recycle" OR "recycling" OR "reuse" OR "net zero") AND ("carbon" OR "decarboni*ation" OR "wood" OR "chemical*" OR "effluent") AND "challenge*" AND ("paper and pulp" OR "pulp and paper")' within 'TITLE, ABSTRACT, KEYWORDS' limited to document type 'Articles'. In science direct database, the criteria for selection used was '("carbon" OR "decarboni" OR "wood" OR "chemical" OR "effluent") AND ("paper and pulp" OR "pulp and paper")' within the body of the articles restricted to the terms '("sustainable" OR "circular economy" OR "recycle" OR "recycling" OR "reuse" OR "net zero") AND "challenge")' within 'TITLE, ABSTRACT, KEYWORDS'.

The search result from Scopus elicited 143 numbers of articles for the first search, while the subsequent search gave 68 articles. The search result from Science Direct generated 405 numbers of articles (Table.1). Out of the same, through further scrutiny of the titles and reading through the abstracts, only 54 number of articles from Scopus and 33 number of articles from Science Direct were found to be relevant to the subject of concern and so the rest articles were excluded from the study. (Table.1). Out of the same, 07 papers were found to be overlapping across both the databases. Excluding the repeat articles, a total of 80 articles pertaining to the interest of the paper under study were selected for examination.

Table 1. Search results across the databases used for literature extraction

Databases	Articles obtained	Articles excluded	Exclusion criteria	Shortlisted articles	Exclusion of repeat articles	Final articles selected
Scopus	143	117	Scrutiny of Title and Abstract	26	07	80
	68	40	Scrutiny of Title and Abstract	28		
Science Direct	405	372	Scrutiny of Title and Abstract	33		

3. Data Analysis

3.1 Bibliometric Analysis

With the objective to perform Bibliometric analysis, the R-package, 'bibliometrix' was used. According to Aria and Cuccurullo (2017) bibliometrix is the most preferred open-source software tool for quantitative research in bibliometrics having best techniques of statistical algorithms, quality numerical routines, integrating data visualization tools and certain inbuilt data cleaning options and offers the most comprehensive science mapping of scientific literature. Further the platform is highly compatible with the bibliometric database, Scopus and automatically connects with Scopus API to collect metadata. The details of articles obtained from Science Direct were merged with that of the 54 articles obtained from Scopus in the csv file format of Scopus and so a combined csv file of 80 articles was used to extract bibliometric inference. In order to capture the research objectives stated for the study, the following graphs and plots are discussed as bibliometric inference:

3.1.1 Annual Scientific Production

This graph is expected to present the trajectory of academic discourse on pulp and paper industry related to its (un)sustainable practices over the years. Given the recent global focus on sustainability on environmental, social as well as economic dimensions, it would be worthwhile to see if the academic community is at par with the global concern in identifying the issues of sustainability in pulp and paper industry and discussing the same with vigor.

3.1.2 Sources Description

The plot on sources description will highlight the journals which are at the forefront in discussing the sustainability issue in pulp and paper industry and the journals which are not that active or are dormant. It would also be worthwhile to figure out whether the journals, which go by the nomenclature referring to sustainable or clean operations, truly are practicing what they preach.

3.1.3 Word Dynamics

Whereas Word Frequency presents the most discussed word within the bibliographic collection, the plot Word dynamics presents the evolution of the words or concepts under discussion over a temporal scale. This plot will throw some light on the evolving words or concepts of concern related to sustainability, as perceived from the academic studies, plaguing the pulp and paper industry at any given point in time.

3.1.4 Thematic Evolution

This plot was considered in the analysis as it would also throw light on the temporal evolution of the themes on discussion concerning sustainability in pulp and paper industry, quite similar to the Word Dynamics.

3.2 Content Analysis

For the purpose of content analysis, the literature collection resulting out of the Scopus and Science Direct database search were inspected. Out of the entire bibliographic collection of 80 articles out of the search results, 20 relevant articles were considered for detailed study and content analysis for identification of challenges of sustainability in pulp and paper industry. The selection of articles were restricted to only 20, as the idea was to capture the most prominent and broadly discussed challenges in the literature, rather than going deep into specific engineering or technical evaluation of the challenges therein.

4. Results and Discussions

4.1 Bibliometric Analysis

4.1.1 Annual Scientific Production

The time span of total number of 80 articles on the domain is 26 years with first article published in 1996 and last article under consideration being published in 2022 (Figure.1). The annual growth rate of the articles in the present field of interest over 26 years is 10.03%. A total of 259 authors have contributed cumulatively in these 80 articles. On an average, the number of co-authors per document is computed as 3.42. From the plot depicting annual growth of the journals under Figure.1, it can be inferred that the publication of the papers on the domain of sustainability of paper and pulp industry has picked up pace from 2008 onwards with focal publications happening only recently from 2018 onwards. Though the exponential growth visible during the recent years can be attributed to the spurt in publication of journal articles during and after COVID-19 Pandemic in general, but the fact that the sharp growth of the publications concerning the subject of sustainability and recycling in paper and pulp industry is visible from 2018 onwards and that the publication growth rate only on the subject of study has touched 12.0% is indicative of the relevance of the issues pertaining to sustainability in paper and pulp industry has found recently.

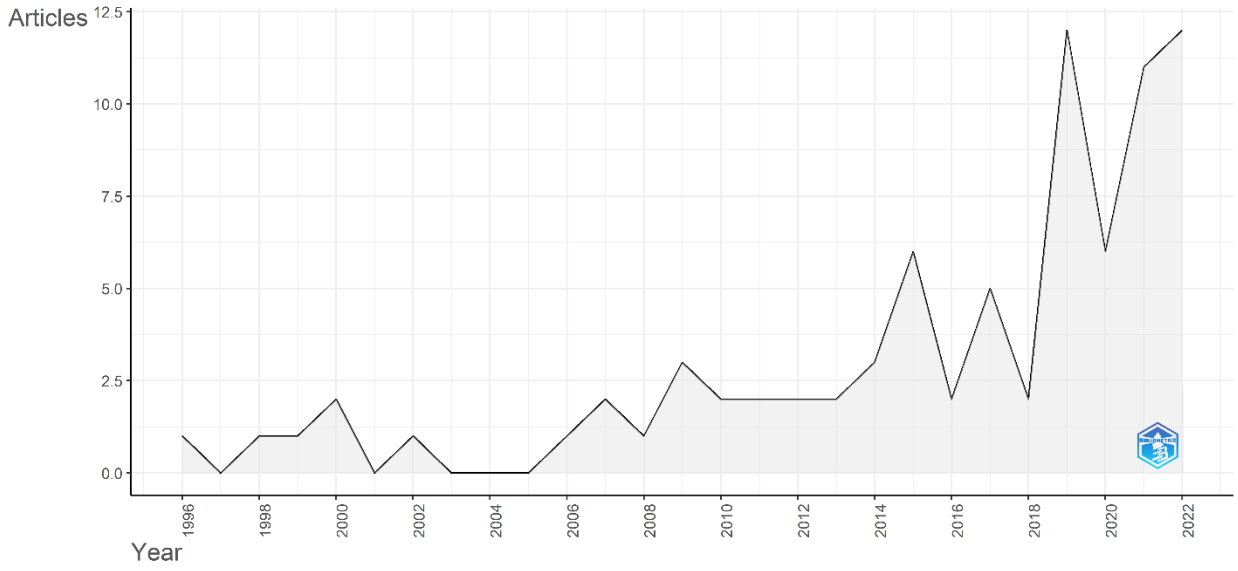

Figure 1. Year-wise annual scientific production of the bibliometric collection

4.1.2 Sources' Description

A total number of sources or journals publishing the 80 articles of interest is 50. Out of the said 50 sources, the frequency of top10 most relevant or contributing sources are as depicted below (Figure.2). As can be observed, the highest number of papers (11) relevant to our subject matter, ie., sustainability in paper and pulp industry, has been published under Journal of Cleaner Production, followed by IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association (6). Two journals, namely, Forest Policy and Economics and Renewable and sustainable energy reviews, feature jointly at the third spot from the top in terms of the number of articles published (4 documents each). Rest 06 sources such as Business Strategy and The Environment, Chemosphere, Energy, Journal of Environmental Management, Paper technology and Paper360 have published 02 articles each pertaining to sustainable pulp and paper industry.

Sources	Articles
JOURNAL OF CLEANER PRODUCTION	11
IPPTA: QUARTERLY JOURNAL OF INDIAN PULP AND PAPER TECHNICAL ASSOCIATION	6
FOREST POLICY AND ECONOMICS	4
RENEWABLE AND SUSTAINABLE ENERGY REVIEWS	4
BUSINESS STRATEGY AND THE ENVIRONMENT	2
CHEMOSPHERE	2
ENERGY	2
JOURNAL OF ENVIRONMENTAL MANAGEMENT	2
PAPER TECHNOLOGY	2
PAPER360	2

Figure 2. Most relevant sources of articles

That the major contributor to the discussion on the sustainability and recycling issues in paper and pulp industry has been 'Journal of Cleaner Production'(JoCP), is also evident from the Source Dynamics plot (Figure.3), even though it was the Journal of Environmental Management which published the first article of our interest in the year 1996. Subsequently, the journal continued to lead the race in term of a leading publisher of the articles on sustainable paper and pulp industry till 2012 from which point the position was occupied by the quarterly journal of 'Indian Pulp and Paper Technical Association'(IPPTA), which continued to hold the place as the leading publisher till 2018. Since 2018 till 2022, the Journal of Cleaner Production (JoCP) has been at the forefront of publishing maximum

number of documents concerning sustainability in paper and pulp industry. In fact, growth of the number of such articles published in JoCP has seen a sharp climb since 2014 which might be construed as the relevance accorded to

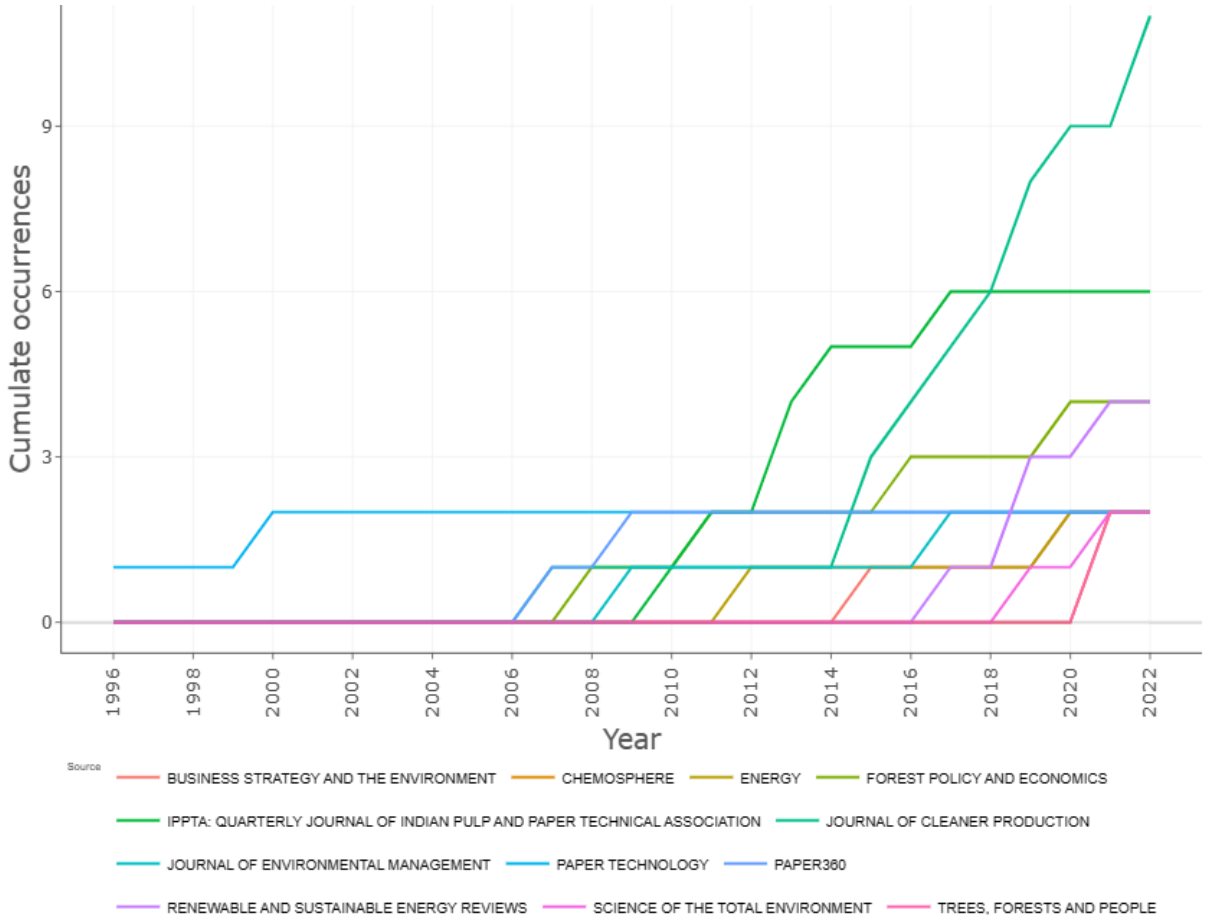

Figure 3. Graph showing the cumulative occurrences of journals over the years.

and its ability to capture the burning issue of sustainability in paper and pulp industry by JoCP. This might also be due to the compounding effect with authors researching on the above domain preferring JoCP over other journals for publication of their articles. So, it may be inferred that JoCP and IPPTA have been able to capture the burning issue better.

4.1.3 Word dynamics

The word dynamics plot presents a visual description of the top 10 words as on 2022, discussed in the bibliographic collection, along with the historical cumulative occurrences. From the plot at Figure.4 below, it can be seen that the most discussed words as on 2022 are ‘paper and pulp industry’ and ‘sustainable development’. The ranking of the words at the first and second position of relevance is not surprising as the keywords were a part of the search criteria for selection of the articles. Yet, the sudden emergence of the concepts from 2020 onwards is an indication that academic discourse on sustainable pulp and paper industry is bustling under active mode. But, listing of the word “Recycling” at third position as on 2022 and seen to be dominating the word list from 1996 to 2020 in the present bibliographic pool of study implies that predominantly the focus of journal articles on pulp and paper industry from 1996 till 2020 revolved around recycling activities, which could be related to the effluents, the quintessential and the most toxic by-product of the process, though the discourse was been fairly consistent even till 2022, as is event from the trajectory of occurrence. Other words featuring in the list of top 10 prominent words as on 2022, in the order of relevance are ‘supply chains’, ‘forestry’, ‘paper’, ‘pulp’, ‘paper industry’, ‘pulp and paper industry’ and ‘supply chain management’ and all of these words were found to have been discussed in the academia from 2005-2006 onwards fairly consistently.

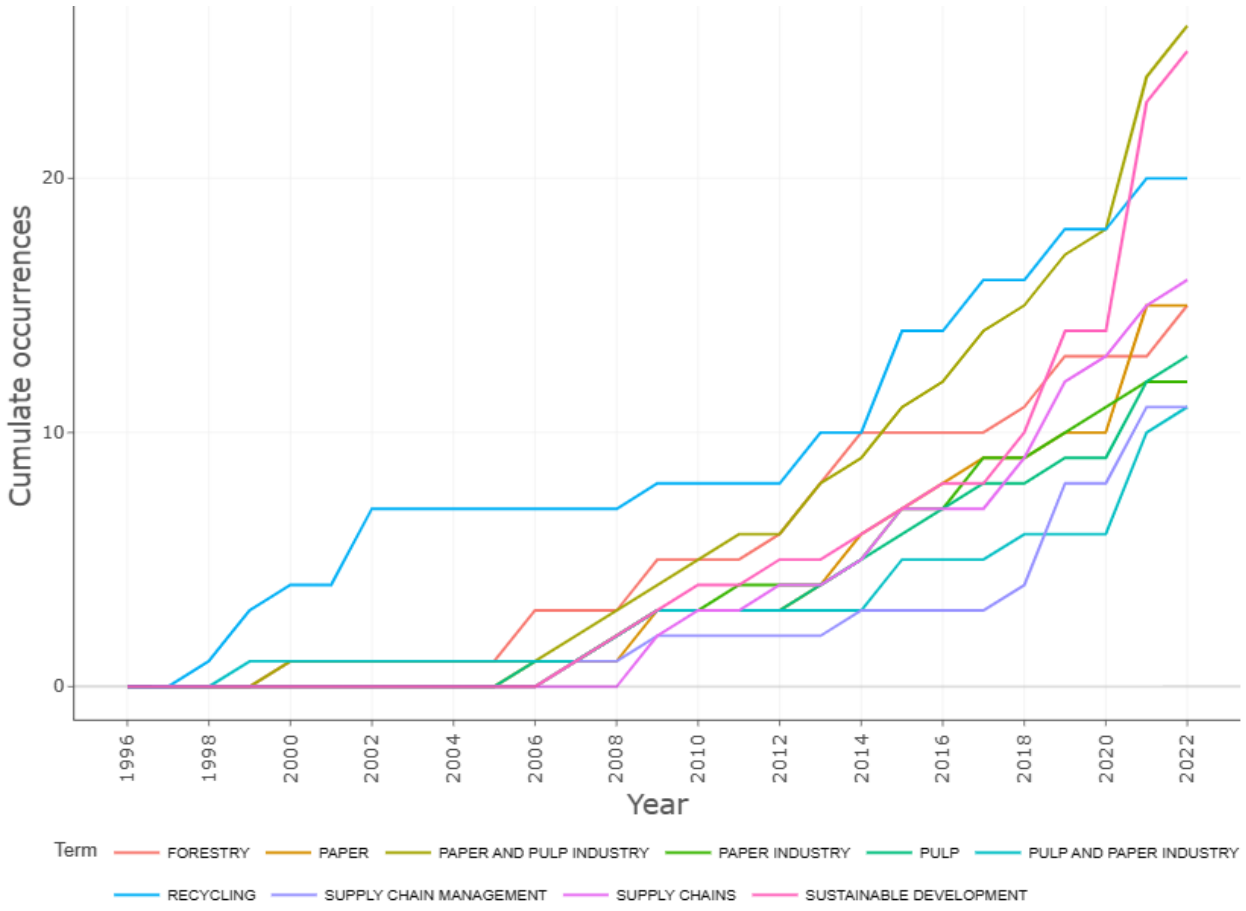

Figure 4. Plot depicting word dynamics in cumulative occurrences over the years

4.1.4 Thematic Evolution

The plot on thematic evolution (Figure.5 below) tells us the gradual progression of literature discourse on sustainability in pulp and paper industry over the period of 26 years from 1996. The plot reveals that the progression of the themes of the articles could be bifurcated into two timelines according to the relevance of the topics of discourse, one from the beginning, i.e, 1996 to 2019 and the second from 2020 to 2022. The primary focus of the themes from 1996 to 2019 has been on topics such as 'effluent treatment' followed by 'forest management' and so on. The terms 'Sustainable development' and 'waste management' were not on top of the most discussed topics between 1996 and 2019. However, during the period from 2020 to 2022, 'sustainable development' was the most discussed topic followed by 'paper and pulp industry' and 'waste management, in that order. On analysis of the plot on Thematic evolution, it can be construed that the prime theme of discussion between 1996 and 2019 on sustainability, circular economy, decarbonisation in paper and pulp industry was 'effluent treatment' followed by 'forest management'. So, even though the theme on 'sustainable development' featured at later positions between 1996 to 2019, before occupying the position of most discussed themes from 2020 onwards, the essential discourse concerning paper and pulp industry has all throughout been around its unsustainable nature of business involving deforestation and waste generation. It is just that the terminology of 'sustainable development' and 'waste management' were used frequently, which by the way encompasses the concepts of deforestation and effluent generation as could be found out from the literature study. So, the thematic evolution plot indeed confirms the relevant issues plaguing paper and pulp industries.

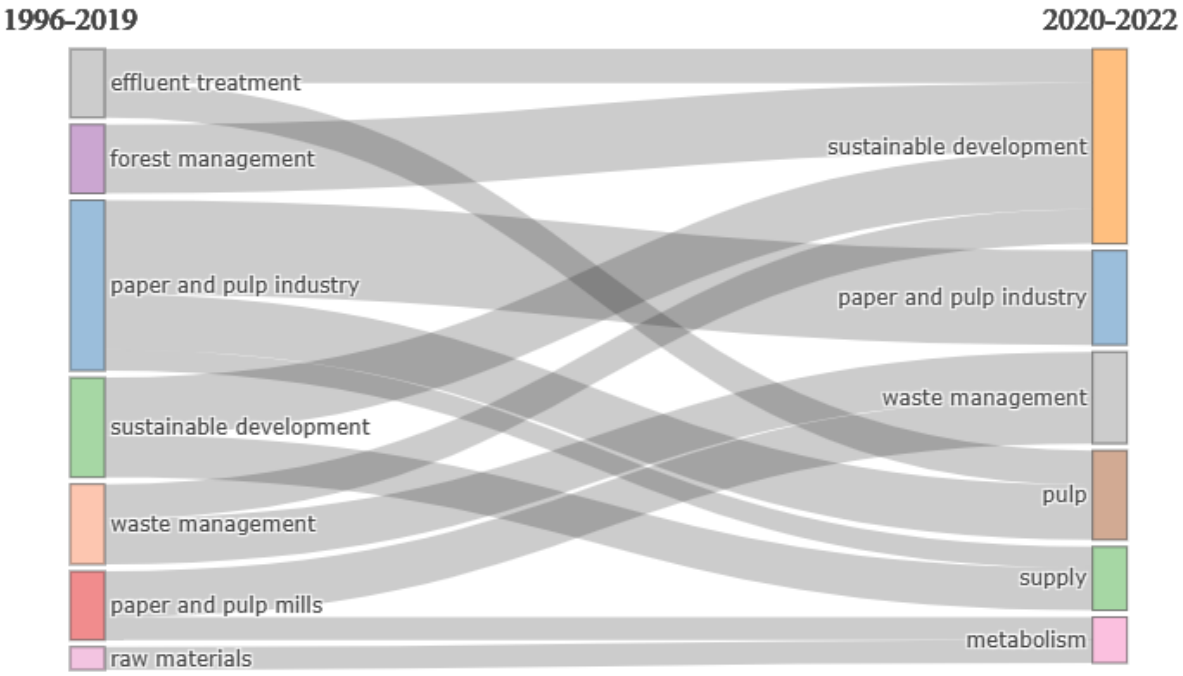

Figure 5. Plot of thematic evolution over the years.

4.2 Challenges for Sustainability

From the analysis of the bibliometric charts as above and on content analysis of 20 most relevant articles out of the bibliometric collection, the following sustainability challenges were identified in the paper and pulp industry:

4.2.1 Depletion of green sources

Being a resource-intensive industry, paper and pulp industry leave a trail of negative impact on natural resources, primary among them being greenhouse effect (Blazejczak and Edler 2000; Pineda-Henson et al. 2002). The major raw material for a paper and pulp industry, throughout the world, is wood (Kulkarni 2013). The only sources of wood are trees. And so, cutting down trees to obtain raw material for the paper and pulp industry is an indispensable part of the paper production process for most of the paper mills (Avs and Demirer 2008). It leads to depletion of green covers which not only are the prime source of oxygen, but also are the prime consumer or absorber of carbon dioxide from the atmosphere. Even during processing of wood, carbon dioxide stored in it is released into the atmosphere. In fact, pulp and paper industry contributes to almost 2% of direct industrial CO_2 emissions (IEA, 2016). So, removing trees contribute heavily to carbon emission and hence propagation of greenhouse gases. As observed by Pant (2021), paper and pulp industry must accord severe attention to protect deforestation due to heavy demand of tree-wood for paper making in countries such as India. The vitality of forest management also clearly emerges out from the thematic evolution under bibliometric analysis above, where 'forest management' has remained a most discussed theme for all the researcher from the beginning (1996) till date (2022). The word 'forestry' also finds high prominence in the word cloud, while being the fifth most referred word in all the articles under study over past 26 years. However, now organisations are taking cognizance of this vital aspect and have started contributing towards decarbonisation through initiatives such as reforestation, switching to non-wood agro-based raw materials, using recycled pulp from disposed or wasted papers as raw materials etc. Even the non-integrated paper making organizations, those purchasing raw material such as wood or pulp from outside, are emphasising on supplier selection. Having environmental certification is gradually becoming one of the prime criteria for supplier selection to ensure sustainability of the environment (Mota et al.2018; Jauhar et al. 2015; Pant et al. 2021).

4.2.2 Energy intensive sector

Paper and pulp industry requires high levels of energy consumption for its paper production process (Setthasakko 2010; Mandeep et al. 2019). The industry ranks among the top five energy consuming industries of the world (Andersson and Thollander 2019). With increasing demand for paper and paperboard world over, consumption of

energy by the paper and pulp industry has increased even further (Kong et al. 2016). Consumption of energy takes place at all stages of pulp and paper making be it during chipping, digesting, pulp washing, bleaching and paper production. As per IEA report (2016) and Man et.al (2019), the pulp and paper industry accounts for almost 6% of total industrial energy consumption in the world. Accordingly, this industry is responsible for gradual depletion of fossil fuels and electricity (Avs and Demirer 2008), leaving the environment and the society to the risk of an unsustainable future. The threat of increasing global warming, caused by the emission of GHGs, can be arrested through reduced industrial energy usage and energy conservation (IPCC 2014; Man et al. 2019). The intensity of energy consumption in the paper and pulp industry is also evident from the fact that the concept of carbon positive or decarbonisation does not feature anywhere in the top 10 most discussed term or topic or theme from the bibliometric analysis. So, it is imperative that innovative technologies and strategies are built into the pulp and paper industry to mitigate energy and environmental loss inflicted to the society (Corcelli et al. 2018). Organizations have now acknowledged the same and innovative measures are being taken towards energy consumption to create a sustainable future. Use of bio-mass (from wood waste), black liquor (a liquid waste ejected during digesting process) and bio-sludge (generated from waste water treatment) in generation of power (Corcelli et al. 2018; EC 2015; IEA 2017) is a reflection towards responsible thinking and sustainable business. Even with increase in paper and paper production by 23% in 2017 over past two decades, the energy usage has only grown by 1% (EC 2015; IEA 2017). Nevertheless, the road to being energy positive in an energy-intensive industry is a long one. Many innovative measures are still to be adopted to restrict energy usage and CO_2 emissions in order to meet the target of limiting global warming to 2^oC by 2025 (IEA 2017).

4.2.3 Extensive water consumption

Another significant contribution by the paper and pulp industry to an unsustainable environment is the extensive use of water, causing severe stress on the water conservation (Setthasakko 2010; Avs and Demirer 2008). Water is primarily used during digesting process for steam generation and washing the cooked and chemically treated pulp (Setthasakko 2010; Corcelli et al. 2018). Even though adoption of circular economy measures in this domain is visible from the industry practices where the clean water generated through effluent treatment of waste water are being recycled back into the system thereby conserving water usage, still exploitation of water from natural resources is a reality in paper and pulp industry as reflected in the literature depicted under thematic evolution plot. And so, further discussions, propositions and actions are warranted to make the paper and pulp industry water positive, if we aim for a sustainable water resource for future generation.

4.2.4 Role of toxic chemicals

Chemicals are the quintessential by-products as well as raw materials at multiple stage of paper making in the paper and pulp industry. The chemicals are consumed during the process of digesting and bleaching and released, as by-products, during the process of digesting (black liquor), pulp washing and bleaching (Corcelli et al. 2018; Man et al. 2019). Even the application of the chemicals as fertilizers used during the eucalyptus plantation (prominent source of wood for paper making industry) contributes adversely to the environment (Xu & Becker 2012). These chemicals are very harmful and cause human toxicity, ecological toxicity, acidification among others (Blazejczak and Edler 2000; Pineda-Henson et al. 2002). Laden with chemicals, the effluents are discharged into rivers or other water bodies by many organizations, thereby leaving a negative impact on both the society and the environment, including damage to human health and other living organisms (Setthasakko 2010). Increasing spread of water-borne diseases world over is an obvious testimony to such threats of industrial byproducts.

This threat can be addressed through effective effluent treatment and recycling or proper treatment of other harmful by-products of a paper making process. However, even in this regard, from a moral standpoint and also in view of rising consumer and societal interest, wide awareness on environmental and social responsibility is gaining ground amongst the business community. Effluent treatment has become almost a conventional part of the paper making process, whereby the waste water are not only treated to distill the liquid of toxic chemicals, but both the treated water and the biosludge are being channeled through respective value chains for recycling into external and internal consumption respectively. In fact, the recycling technology of black liquor and the biosludge to meet the energy requirement (Corcelli et al. 2018) is contributing to energy conservation and hence serving as an added bonus to the society, environment and the business community. In fact this could also be the reason why ‘recycling’ featured as a most discussed word in bibliometric analysis. In spite of the above direction of development, with the threat of global warming and unsustainable resources, including that of contaminated and scarce water sources, looming over the future of a sustainable biosphere and with ever demanding consumers and the vigilant civil society, it remains a challenge not only to restrain the penetration of harmful effluents into the society but also to contribute to the society more than what is taken from it.

4.3 Proposed Improvements

The challenges emerging out of the literature clearly warrant transformation, not just in terms of the business processes and operations, but also change in the worldview held by the industrial community as a whole encompassing the entire supply chain of pulp and paper industry. Given the processual challenges discussed above, the following improvements may be considered as the mitigating forces for such challenges:

4.3.1 Re-forestation or Afforestation

Considering the act of uprooting of trees a routine affair for a wood based pulp and paper industry, this operation could be coupled with sampling plantation measures. For tree which is uprooted, all firms may consider planting atleast 2-3 samplings. The saplings could be of the same variety of trees or could be a mix of the desired variety with some most eco-friendly ones. It might take some years to actually give off the benefits of sustainability, but once the system is in order after the first few years of inception, it will be a perennial design of mitigating the issue due to deforestation.

4.3.2 Renewable sources of energy consumption

Pulp and paper industry will continue to remain an energy intensive industry, unless the industry is bombarded with some new disruptive technologies. So, the best way to address the hurdle of fossil fuel consumption as well as emission of greenhouse gases is to make use of renewable energy sources. With the tariff of renewable energy seeing a downward progress, economic feasibility of introducing such sources could be explored in depth. Also, the pulp and paper making process itself offers multiple avenues of recycling its waste for sustainable consumption, prime among which is energy. The wood dust or scrap generated during wood chipping and black liquor during digesting are very useful renewable fuel sources.

4.3.3 Water recycling and rain-water harvesting

As with energy sources, the consumption of water for a pulp and paper making process awaits some revolutionary technology to reduce water intake per unit of pulp and paper production. Till such time, recycling of water through efficient and effective treatment of waste water is a most feasible solution to address the threat of incessant water consumption in this industry. Also, as an industrywide practice, efforts may be pulled towards implementing rain-water harvesting projects from the water sourcing regions and the surrounding vicinity.

4.3.4 Effluent treatment

The toxicity of chemicals released by way of effluents can be completely isolated from environmental diffusion through effective effluent treatment plans. In fact, through effective effluent treatment many pulp and paper making firms are able to recycle the chemical back into the production process, thereby restricting the toxic effects of the chemicals to spread into the atmosphere, while also making the firm more resourceful in terms of use of chemicals for paper making process.

Apart from the measures related to the pulp and paper making industry, the following improvements are proposed for the academic community for making greater contribution to making this industry a sustainable one:

4.3.5 Research on state-of-the-art technologies

The technology for pulp and paper making has still broadly remained the same over its long history. Research studies focusing on how state of the art technologies can be utilized in the pulp and paper industry need to be encouraged to bring about a discernible transformation for making the process of pulp and paper making more sustainable and resourceful. Studies on how digital technologies can improve the processes through some experimental data would be more appreciated and considered reliable for the practitioners in the industry. Simulation studies could also be presented through research publications for the industry audience for their consideration.

4.3.6 Wider discourse on prominent journals

Barring one or two journals, the academic dissemination of sustainability issues in pulp and paper industry has largely fallen behind, given the global discussion on the topic taking the hot seat. So, encouraging active research and publication on the area of sustainable pulp and paper industry is a must, if we wish to strive to achieve sustainable living and consumption in a targeted time frame.

5. Conclusion

Through the bibliometric analysis and study of the articles covered by the bibliometric collection, the state of the literary discourse and discussions on environmental impact of paper and pulp industry was discussed. The discussions on the issues of sustainability pertaining to the paper and pulp industry, in the academic world, were studied through the journal-wise and article-wise analysis using bibliometric tool. Further, various challenges for sustainable business practices in the paper and pulp industry, identified from the bibliometric collection were discussed. On the basis of the research outcome, few suggestions of improvement were proposed. From this paper, it is evident that paper and pulp businesses all throughout had major environmental and societal concerns and threats which are ingrained in their business models. However, with rising awareness and concerns not just amongst the society at large, but also amongst the customers and the organisations themselves, several measures to mitigate the adverse effects resulting from the business models of paper and pulp industries are being adopted. Yet, achieving a completely sustainable and environment friendly model of paper making is a far cry. And so, further discussions, propositions and actions, as proposed above, are desired to make the paper making business a net resource contributor to the society from a net resource consumer as per the present time.

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