

An Analysis of the Environmental Effects of Paper Manufacturing

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ABSTRACT

For the past century, ruled paper has served an important role in facilitating the education of our students around the world. However, the paper manufacturing industry has a devastating environmental impact on our planet. On average, approximately 68 million trees are cut down each year for paper products. Additionally, in the past two decades, paper usage has risen 126% from 92 million tons of paper to 208 million tons^[1]. The environmental effects of paper manufacturing are not limited to resource costs; pollution is also a byproduct of paper production. Harmful substances, such as sulfur oxides, nitrogen oxides, and reduced sulfur gasses, are produced from the paper production process. Chlorophenol, another byproduct, when ingested in high levels, has adverse effects on the liver and immune system of animals. The manufacture of paper has heavy resource usage as well: 10 liters of water are consumed to make a single sheet of A4 paper^[2]. Furthermore, paper itself continues to negatively impact the environment even after use. Approximately 80% of discarded ruled paper decomposes in landfills. The decomposition of paper yields methane, a greenhouse gas with 21 times the heat-trapping power of carbon dioxide. Landfills also contribute to the majority of methane emissions, with paper accounting for approximately 38% of the municipal solid waste stream^[3]. In this study, we analyze the harmful environmental impacts of paper production, including waste byproduct, air pollutants, resource costs, and more.

Keywords: paper, pulp, trees, pollution, greenhouse gases

1. INTRODUCTION

The paper industry produces millions of metric tons of paper per year. In schools alone, 34 billion sheets of paper are used worldwide annually^[4]. Our heavy reliance on paper has led to the industrialization of paper production in the past few centuries. Paper mills, aside from manufacturing paper, also produce a large amount of pollution. Canada and the United States produce the third and sixth most amounts of pollution from the pulp and paper industry respectively. In 2015, the pulp and paper industry was responsible for 174,000 metric tons of emissions in Canada; in the U.S., it was responsible for 79,000 metric tons of emissions. These emissions include dioxins, furans, hexachlorobenzene, and more, all of which are persistent, bioaccumulative, and toxic chemicals (PBTs). Carbon dioxide, nitrogen oxides, and sulfur oxides are also byproducts of pulp and paper manufacturing. Nitrogen and sulfur oxides react with

molecules in the atmosphere to form acid rain which is highly corrosive to biological matter. Carbon dioxide, a greenhouse gas, is a large contributor to climate change. The pulp and paper industry in Canada and the U.S. is responsible for approximately 10% of industrial fine particulate matter. Fine particulate matter is small enough to penetrate the respiratory system and has a detrimental effect on health. Pulp and paper manufacture also creates wastewater containing both organic and inorganic pollutants. This includes nitrogen and phosphorus, substances that cause eutrophication of freshwater bodies like rivers or lakes. Additionally, the industry produces lead as a byproduct and disposes of it in water. In Canada, the pulp and paper industry ranked third highest in lead emissions to water. High-level lead exposure and ingestion can cause anemia, weakness, kidney, and brain damage. It is also a teratogen and can harm the developing nervous system of a fetus. The pulp and paper industry, in 2015, was first in the amount of toxic weighted pound equivalents released to water by industry. A majority came of this came from manganese compounds, hydrogen sulfide, dioxin compounds, and more. Long-term exposure to dioxin and dioxin-based compounds are linked to impairment of the nervous system, endocrine system, immune system, and reproductive system. In terms of solid pollution, municipal waste is 26% comprised of paper waste in 2014. The decomposition of this paper waste produces a large amount of methane, a greenhouse gas with 21 times the heat-trapping capability of carbon dioxide. Paper consumption has also seen an increase of 400% in the past four decades, which also means an increase in emissions. Thus, the paper and pulp industry creates a large environmental issue that needs to be addressed.

2. HISTORY, TRENDS, AND CHANGES

Over the past century, the pulp and paper industry has grown at an exponential rate, capable of mass manufacturing hundreds of thousands of sheets of paper every day. Since World War I, demand for paper products skyrocketed, resulting in massive growth in the U.S. pulp and paper industry^[5]. At the time, little concern was given to the environmental impacts of manufacturing paper. It was only until the 1970s when environmental movements in the U.S. began to regulate and limit the American pulp and paper industry. In 1974, the Environmental Protection Agency (EPA) first issued effluent guidelines for the industry. They set numerical limitations on many different pollutants, such as biochemical oxygen demand (BOD), fecal coliform bacteria, oil and grease, pH levels, and total suspended solids (TSS)^[6]. However, it was only until 8 years later when the EPA adjust their regulations. In 1982, the EPA modified their regulations to limit pentachlorophenol, trichlorophenol, and zinc levels. These new effluent limitations were implemented in National Pollutant Discharge Elimination System (NPDES) permits, which had to be renewed every 5 years^[7]. After this, the EPA delayed twice as long as compared to before until revising their regulations. In 1998, a long 16 years after the implementation of the NPDES, the EPA implements the “Cluster Rule” (CR). It addressed additional toxic wastewater pollutants and regulated hazardous air pollutant emissions. Despite

this change, the cluster rule was not enforced until 3 years later, allowing many large paper manufacturers to exploit the lack of enforcement. Around 2001, the air emissions regulations in the Cluster Rule were finally made effective. They were also known as “Maximum Achievable Control Technology” (MACT) regulations and applied to both mills that utilized chemical pulping and mills that used chlorine bleaching in combination with kraft chemical pulping. For mills using chemical pulping, hazardous air pollutant limits, volatile organic carbon limits, and particulate matter limits were reduced 59%, 49%, and 37% respectively. For mills using chlorine bleaching and kraft chemical pulping, dioxin discharge, furan discharge, and chloroform discharge level limits were reduced 96%, 96%, and 99% respectively^[8]. In Canada, three federal regulations set the standard for pollution levels regarding the pulp and paper industry. The Pulp and Paper Effluent Regulations based their standard for the level of acute lethality to fish, biochemical oxygen demand (BOD), and total suspended solids (TSS)^[9]. Pulp mills also had to monitor the environment to determine the biological impact of their effluents. The Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations were targeted at polychlorinated dibenzo-para-dioxins and polychlorinated dibenzofurans in mill effluents^[10]. The Pulp and Paper Mill Defoamer and Wood Chip Regulation limits the use of defoamers containing dibenzofuran or dibenzo-para-dioxin at pulp and paper mills using a chlorine bleaching process^[11]. It is evident that environmental regulations concerning the pulp and paper industry is only a relatively new development. Paper mills were created starting from the 17th century while environmental regulations on the industry came around in the 20th century.

Deforestation was yet another negative result of paper manufacturing. Up until 1992, there were no common standards for deforestation and management of forests; pulp and paper industries had unbarred access to trees worldwide and exploited this opportunity. During this year, the United Nations Conference on Environmental Development set definitive standards for sustainable forestry, including the proper management, reforestation, growth, and nurturing of forests^[12]. In the conference, measures for both managing land resources and combating deforestation were proposed. The United Nations outlined policies to encourage active participation of those affected by deforestation, especially minorities such as youth, women, and indigenous peoples. Additionally, strengthening existing systems and procedures for environmental, economic, and social data relating to land resource at all levels were emphasized. The economic costs total \$50 million annually to implement the activities necessary to manage land resources. In terms of combating deforestation, the United Nations highlighted better education and awareness about forest management and deforestation impact. Investment studies concerning supply-demand harmonization and responsible logging were also activities considered. In all, it was estimated that \$2.5 billion was required for implementing methods to reduce or manage deforestation. Around the same time, the United States also began enforcing state and federal forest management laws. Along with the voluntary compliance of landowners, the United States maintained hundreds of millions of acres of forestland. All of this was a strong

step in the direction of sustainability and helped pioneer an eco-friendly agenda. However, to this day, deforestation remains a massive issue. Although the United States and other first-world countries follow forest management laws and are environment-conscious, many underdeveloped countries continue to engage in irresponsible logging. To illustrate, Indonesia, Thailand, and Malaysia have no certification programs in place, meaning that their logging areas are not officially certified as sustainable. Environmentally-conscious organizations, such as Greenpeace and Rainforest Alliance, called them out on taking advantage of the lack of regulation. Specifically, Asia Pulp and Paper (APP) is notorious for irresponsible logging and has consistently exploited underdeveloped countries' lack of environmental regulations for deforesting. APRIL, the second largest paper manufacturer in Indonesia, also refuses to adopt sustainable forestry policies. They deforest around 600,000 hectares of tropical forest annually. In general, based on reports from Greenpeace, around 80% of logging in Indonesia is illegal. The reason for their exploitation of the lack of environmental regulations concerning deforestation is due to a high demand for paper. As underdeveloped countries fall behind in terms of technological advancement, they do not have access to digital mediums and alternatives to paper products. Thus, they must rely more on traditional paper mediums^[14].

Since the advent of industrialization, the pulp and paper industry began to source their production to third-world, developing countries. Not only do these countries have significantly cheaper labor costs, but they typically also have looser environmental regulations and faster-growing markets for paper products. In the early 2000s, comparing China and the United States, an average Chinese paper mill worker would earn a wage of \$1/hour (adjusted for currency) with no pension. Meanwhile, the average American paper mill worker would earn a wage of \$28/hour with both healthcare and pension benefits. The disparity in wage gap and looser environmental rules has given great incentive for pulp mills to outsource their production overseas to countries like China, Africa, and more^[15].

In the future, the pulp and paper industry will also be greatly influenced by ongoing innovational trends in the coming decades. E-commerce, an increasingly popular method of shopping, forces the pulp and paper industry to come up with new packaging solutions. Because a large proportion of shopping is done online, producers must come up with better, more appealing packaging to maximize their consumption on the traditional retail market. Additionally, industry costs are being driven down due to the recent innovations of big data analytics, artificial intelligence, and more. Big data analytics has multiple applications in the pulp and paper industry in terms of marketing, sales, production optimization, and maintenance. In process control, basis weight, moisture, and other properties' analytics are collected from fast-running paper machines; the gathered data is used to optimize the process control. Big data also has applications in forestry operations: it can be used to evaluate growth and volume of harvestable trees for wood supply^[16]. One notable instance of big data usage to aid forestry operations and raise environmental awareness is Google's Global Forest Watch 2.0, an

interactive, real-time forest monitoring system. It combines big data gathered from remote sensors, human observation, and satellite imagery to help forests management efforts^[15]. Intelligent sensors is another innovation that increasing optimization to decrease cost. Such sensors are developed and applied to different parts in the papermaking process. They are able to measure factors such as flow, temperature, pH, consistency, and more; the sensors aid in self-monitoring and configuration of the complex processes in paper production.

In addition to new innovations, the rise of eco-friendly sentiments in the past decade are projected to influence the pulp and paper industry. Recyclability is increasingly becoming a key requirement for paper products. For the packaging of paper products, there has been pressure related to the recycling of plastic waste; the European Union set a target to collect and recycle 55% of all plastic packages by 2030^[14]. Anti-plastic sentiments have also encouraged the pulp and paper industry to invest in biodegradable alternatives. In particular, they have looked into the use of plant-based raw materials. Much of the conversion to more eco-friendly options has been driven by health-conscious governmental agencies and consumers^[17].

Furthermore, market growth trends have reflected a decline in the pulp and paper industry. Per Resource Information Systems Inc. (RISI), an analysis in February 2019 showed that graphic paper production declined from 2010 to 2018. Graphic paper which includes printing, writing, and newsprint type paper declined a total of 7.6% in total, with newsprint declining 6.1% and printing and writing declining 1.5% in terms of compound annual growth rate. In the upcoming decade, graphic paper will likely continue to face severe decline in demand and significant pressure to restructure their production capacity. Countries around the world are increasingly turning towards digital media and methods of communication. Additionally, due to the rise of ecommerce, paper advertisements are also being used less than before. Overall, the pulp and paper industry is seeing a decline coming into the next decade. To continue operating, machinery in the industry may be repurposed for packaging and speciality papers; the industry could also turn to more innovative structural moves such as modifications to their distribution and supply chain^[18].

The pulp and paper industry itself has also seen significant changes in their production processes in the past few decades. Before the 1990s, chemical pulps produced by the kraft or sulfite processes utilized chlorine and chlorine-based compounds in the bleaching of wood pulp. In 1990, elemental chlorine was used in over 90% of kraft pulp production globally^[12]. Using elemental chlorine on plant life has shown to produce large amounts of dioxins which are persistent organic pollutants (POP). These persistent organic pollutants (POPs) can result in increased cancer risk, reproductive disorders, averse immune system changes, neurobehavioral impairment, and more^[19]. Afterwards, the usage of elemental chlorine the bleaching process was significantly reduced: in 2005, elemental chlorine was only used in approximately 20% of kraft pulp production worldwide. Instead, the industry turned to elemental chlorine free (ECF) and

totally chlorine free (TCF) bleaching processes. Subsequently, dioxin production declined as well^[12].

3. CONCLUSION

Paper manufacturing has massive implications on the future of our world. The pulp and paper industry utilizes many harmful chemicals such as dioxins, furans, hexachlorobenzene, sulfur and nitrogen oxides, and more. Many of these chemicals are used in the paper production process, putting workers there at risk of developing disease or illness. Additionally, substances like sulfur and nitrogen oxides result in acid rain which is harmful to organisms. The materials required to produce paper are also procured at a cost of negative environmental impact. Deforestation has been at the forefront of environmental issues with the pulp and paper industry; billions of trees have been cut down every year, resulting in increasing carbon emissions and air pollutions. Paper mills generate pollution that enters air, land, and water, making paper manufacturing extremely costly. Recycling and reusing paper products helps alleviate many of these issues. In the past few decades, the consumption of recycled paper has been continuously increasing due to better technology, healthy price competitiveness of recycled fibers, environmental awareness efforts from both consumers and producers, and governmental regulation influencing demand for recycled paper. By recycling, pulp fibers are sourced from already manufactured paper, decreasing our need to deforest and thus reducing our environmental footprint. Using recycled pulp fibers is far less energy-demanding and uses smaller amounts of chemicals. On the other hand, the use of recycled fibers has a limit. Repeated use of secondary fibers worsens the paper's properties due to fiber deterioration; the main issue is the decrease of the pulp's mechanical properties, mainly paper strength. Additionally, using recycled paper, albeit less energy-costly, uses energy derived from fossil fuels since creating the secondary pulp requires a supply of thermal energy to dry the paper web. Ultimately, however, the benefits of utilizing secondary pulp and using recycled fibers significantly decreases the negative effects of paper production using virgin fibers. It drives down material costs, as less capital and labor needs to be spent on cutting down trees^[20]. The same paper can also be used multiple times, ensuring that each sheet of paper is utilized to its full potential. Furthermore, it reduces pollution even after the manufacturing process. By using secondary pulp, existing paper is taken out of landfills, reducing carbon dioxide and methane emissions while also reducing the need to build new landfills. Wastewater stream toxicity and production are also reduced, further lessening the pulp and paper industry's negative ecological effects on freshwater ecosystems. Thus, the world would benefit greatly if pulp and paper industries utilized secondary pulp fibers and recycled paper in their production processes. Not only would it benefit the environment, but production plants would also be able to drive down their production costs^[21].

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