Sustainable Paper Production From Algae: A Novel Approach To Mitigate Environmental Pollution.

Yogini A. Ranade[1], Vaishnavi B. Rindhe[2], Krutika S. Patil[2]

[1] Assistant Professor, Department of Biotechnology, Deogiri College, Chhatrapati Sambhajinagar, M.H, India

[2] Student, Department of Biotechnology, Deogiri College, Chhatrapati Sambhajinagar, M.H, India

ranadeyogini2@gmail.com, vrindhe18@gmail.com, rutika0307@gmail.com

1. ABSTRACT

Over-utilization of paper and paperboard in India, which shares 4.72% of world consumption, has serious environmental effects like deforestation, pollution, and an ascent in carbon emission. This is also the world-wide concern which must be addressed effectively with priority. Conventional papermaking from cellulose and lingo-cellulosic components is an inception of the problem. Pithophora oedogonia as a bizarre source for cellulose, a sustainable solution to relieve ecological issues connected with conventional paper production, are examined in this work. Algae, which are normally considered a nuisance in water bodies, can be used to create paper, reduce the use of traditional materials and reducing the environmental foot print of their disposal. The study proves the viability of creating paper from algae, using an economically friendly, flexible, and environmentally friendly process. The algal paper is organic, biodegradable, and can be naturally intentional with organic glue and bleaching agents. The discovery through Google survey from a diverse pool of respondents demonstrates a positive recognition of algal paper, establishing its potential as an environmentally friendly option for regular paper. The novel method provides a sustainable solution to pollution management, eco-friendliness, and the creation of an economical friendly paper-producing industry.

Keywords: algal paper, biodegradable, carbon emission, cellulose, conventional papermaking, deforestation, eco-friendliness, environmental effects, over-utilization, paper, paperboard, paper- producing industry, Pithophora oedogonia, pollution sustainable solution.

2. INTRODUCTION

As per the latest statistics, India uses around 22.05 million tons of paper and paperboard annually, representing around 4.72of the world's paper consumption (Maximize Market Research Pvt Ltd, 2024), immense measure of paper usage is an unsolicited and unnoticed issue constantly. There is not a solitary region that has endured in our living where there is no utilization of paper. The formation of papers from conventional sources makes the issue more vulnerable. The environmental impact of this, such as deforestation, pollution, and increase in carbon index global warming and other intimidating issues, are the unending cascade here (Kunak Technologies S.L, 2024). Reusing paper is a much more critical issue as its composition might pollute more.

Therefore, it's the ideal time for us to revolutionize the thought regarding how and from where we could get the paper produced. The conventional sources for paper production includes cellulose and

other lignocellulosic material such as *Gossypium spp. Linum usitatissimum*, grass, straw, *Cannabis sativa, Corchorus spp*. etc. obtained from pulp of different plant parts (Kelly C. Coelho de Carvalho *et. al.*). This utilization commences the issues as deforestation, land acquisition and so on. This study features the utilization of *Pithophora oedogonia* as a nonconventional source for cellulose. The paper created from algae might substitute the traditional territory of paper utilization extensively (Bebbington *et. al*., 2018).

Algae, otherwise known as the "green lungs" of aquatic ecosystems, have a key role in oxygenation and serve as a reservoir of nutrients for other aquatic organisms (Photosynthesis in Aquatic Environments, 2019). Algal blooms, brought about by exorbitant algae growth, can destructively affect aquatic life and populace, including toxins, curtailing dissolved oxygen levels, impaired water quality, and altered nutrient sources of the aquatic ecosystem, prompting financial losses and reducing society's confidence in water management (Amorim & Moura, 2020). The algae proposed in this study, *Pithophora oedogonia* a string alga (Ranade *et. al.*, 2024), is a major river, pond, pool, or aquarium weed, which has to be removed to maintain homeostasis in that aquatic ecosystem. Technologies available to get rid of these algal blooms are either rudimentary giving less efficiency or costly with increased efficiency (Zhan *et al*., 2021).

Thus, using *Pithophora oedogonia* for paper production will solve the issue with dual benefits. It will supplant the conventional material for paper production and tackle the issue that emerged with the disposal of the weed algal bloom. This settles both issues in a sustainable way, fostering a horizon of opportunities for algal use. The *Pithophora oedogonia* requires nothing but only the potable water and sunlight (Ranade *et al.*, 2024). All the nutrients can be fetched from the source water and the advantage of a long spectrum of summer is with our geological area (Singh *et al.*, 2010). Effluents either domestic or industrial can be used for the same after certain steps of detoxification. The *Pithophora oedogonia* can be cultivated as horizontal as well as vertical farming technique solving the land acquisition issue.

The paper is made from low-cost organic, hand-made, and biodegradable raw material with low production and small-scale operation capabilities. There are fewer operations and less automation with less control parameters in the manufacturing process. Organic bleaching agents and unconventional binders increase the biodegradability of these paper. *Sapindus mukorossi* powder can be used as a surfactant for dusting and removal of water bodies (Muntaha & Khan, 2015). Specialized paper may also offer varied natural essences and color, which are low-cost and suitable for field work. The issue of diatoms and small phyto- zooplankton can be overruled by efficient washing of algae after collection. The issue of stagnant water mosquitoes can be overruled by adding Gappi fishes in the cultivation units.

This algal paper might find many proposed applications in the paper industry, advertisement industry, packaging industry, invitation cards, and so on. Paper production requires less cognitive power so people with cognitive disabilities may also be able to go well with the process improving their social status and motor skills as well.

3. OBJECTIVES

Objectives of the study is to control pollution caused by pamphlets, invitation cards, advertisements, brochures etc. the algae used is a weed alga, so from weed we will be able to reduce pollution of other packing materials in the eco friendly alternative. It can be an encouragement as

an eco-friendly alternative for pamphlets. This approach will reduce the pollution caused by the packaging boxes etc.

Firstly to quantify the social, economic, and environmental impact of algal paper and pamphlets, a Google Form was used to collect information from people who use paper on a regular basis. The study asks how many papers they use every day, how many pamphlets they get, and what they do with these pamphlets after receiving them. It also investigates if informant's reuse the materials (Material of Construction) used in the pamphlets and whether they have thought about reusing paper pamphlets, as well as the strategies utilized for this purpose.

The second objective is to investigate the socio-ecological effects of algae removal, including questions about the type of water reservoir (open or closed), whether algae problems are present, the techniques used to remove the algae, disposal procedures, and any particular applications of the algae. It's also critical to determine if algae are viewed as environmental contaminants.

The last objective is to turn algae's annoyance into a sustainable substitute. This raises the question of whether people are aware of paper substitutes and if they are ready to accept algae as a legitimate source of papermaking.

4. MATERIAL AND METHOD

4.1 Materials

The biological components of the algae paper manufacturing process include sting algal blooms (*Pithophora oedogonia*), different cereal (*Triticum*, *Sorghum vulgare*, *Zea mays* starch), and tree trunk glue, the chemical components include vinegar or sodium hydrogen carbonate, and the instrumental components include cultivation tanks (vertical and horizontal tank), washing units, drying units, size reduction units, mixing and blending units, compression units, and packaging units.

4.2 Methodology

1. **Survey and data collection:**

   Before the project started, a Google Form survey was carefully created and put into use. The purpose of this survey was to collect baseline information, participant insights, and views that would guide the project's course.

2. **Algal Collection and Cultivation:**

   Algal cultivation unit was filled with potable water and a seed algal mass (1gm) was added to it. Vertical cultivation unit (12x12 sq feet) was preferred to combat space issue. Additional nutrients ($NaNO_3$, K_2HPO_4, $MgSO_4 \cdot 7H_2O$, $CaCl_2 \cdot 2H_2O$, Citric Acid$\cdot H_2O$, Na_2CO_3 etc) may elevate the speed and luster of algal bloom.

3. **Washing and processing of algae:**

   Cultivated algae was washed thoroughly using moderate speed water sprinkles (42 gallons per hours). Biological washing agents like *Sapindus mukorossi* powder (10gm/L) can be used but cleaned back thoroughly. *Pithophora oedogonia* was then soaked in natural conditioner (*Cocos nucifera* oil (10ml/L)), or *Aloe barbadensis* miller gel (20ml/L), etc) in water containing tank for few hours. Washed algae were then drained by keeping it on aerated porous platform and dried using drying machine.

4. **Cutting, Blending and Pulping process:**

   Dried *Pithophora oedogonia algae* were cut to reduce its size and paste was made with suitable amount of water (Algae: water in 8:2 ratios respectively). This paste was then added to mixing and blended unit with bleaching agent and kept for 2hrs hrs till pulp gets fairly decolorized. The pulp was made free from bleaching agent and drained for excess water. The drained wet pulp was then mixed with binders, colorants and essences if needed and blended thoroughly. This algal pulp

was then sent to paper spraying and compression treys (0.2-0.6MPa) to make paper sheets.

5. Drying ad cutting process:

The paper sheets then shifted to drying section with dryers. The semidried papers were cut in proper shapes and further kept for drying using hot and cold air flows as required. The cut papers are then sent for temper resistant packing and labels were put on it. The algal paper was then ready for being in market.

5. RESULTS

While doing the survey, E-mail addresses from a wide spectrum of participants were collected, including students, teachers, government and commercial sector workers, homemakers, and medical professionals. The majority of responders have degrees in Biotechnology, but some also have B.Com. B. E. and M.Sc. degree holders in addition to other undergraduate and graduate degrees.

The data was analysed and processed as follows. Paper is mostly used for study materials by a sizable percentage (78.7%), with supplementary uses in writing, creating, and official work. Although many respondents are unsure of the precise paper type they use, 58.3% of them indicated that uncoated paper is the most well known variety. Of those surveyed, 82% indicated they have an open water reservoir, while 28.7% mentioned having one at home. 55.1% of participants reported experiencing issues with algae, and 43.5% attempt to manage these problems by disposing of algae in the trash or preventing its growth. There are differing views on whether algae can help reduce pollution; some see it as a pollutant, while others recognize its ability to purify water.

Respondents also identified algae as a source of food, fertilizer, and medicine. Additionally, 62% of those surveyed believe that algae could be utilized for writing or packaging, and they suggested other materials for papermaking, including cotton and sugarcane waste.

Different ingredients of flour and glue in proportions were used to make different varieties of paper. *Pithophora oedogonia* powder, *Triticum aestivum* flour, corn starch, water, organic glue, and glycerin (60:10:10:10:5:5), *Pithophora oedogonia* powder with sorghum flour and water (60:20:20), algae powder with corn starch and organic glue (70:20:10), and *Pithophora oedogonia* powder with waste paper and water (60:20:20). The size of the algal paper is roughly the same for all of them, 8.0 x 11.0 inches, with a thickness of 0.1 mm and a weight of approximately 70 grams. The paper produced using sorghum flour has slightly varying measurements and a thickness of 0.4 mm.

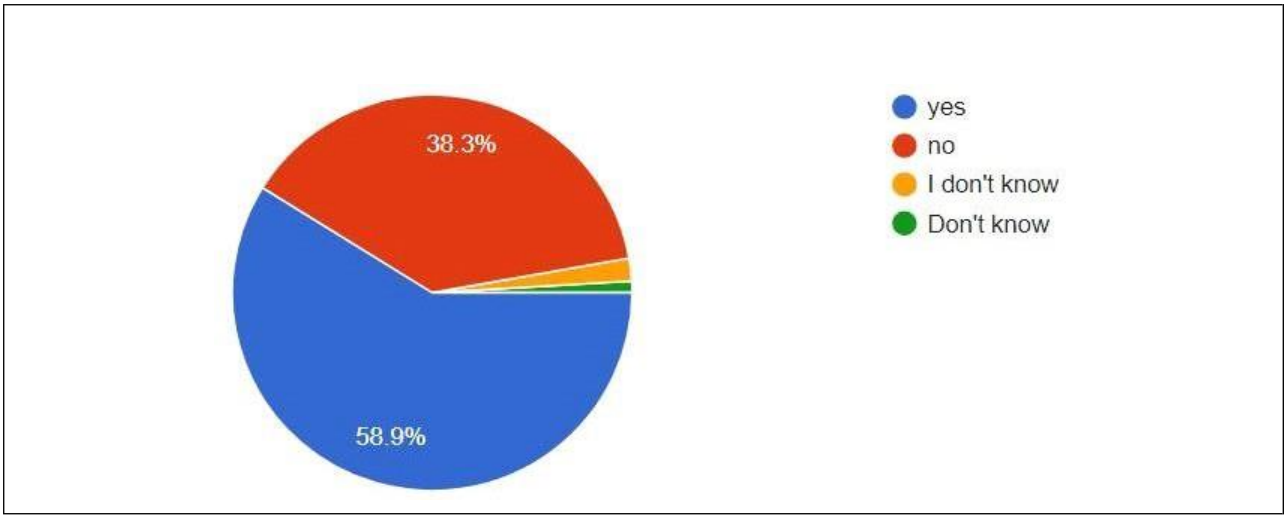

Figure 1: population perspective towards the utilization of algae as an alternative of paper

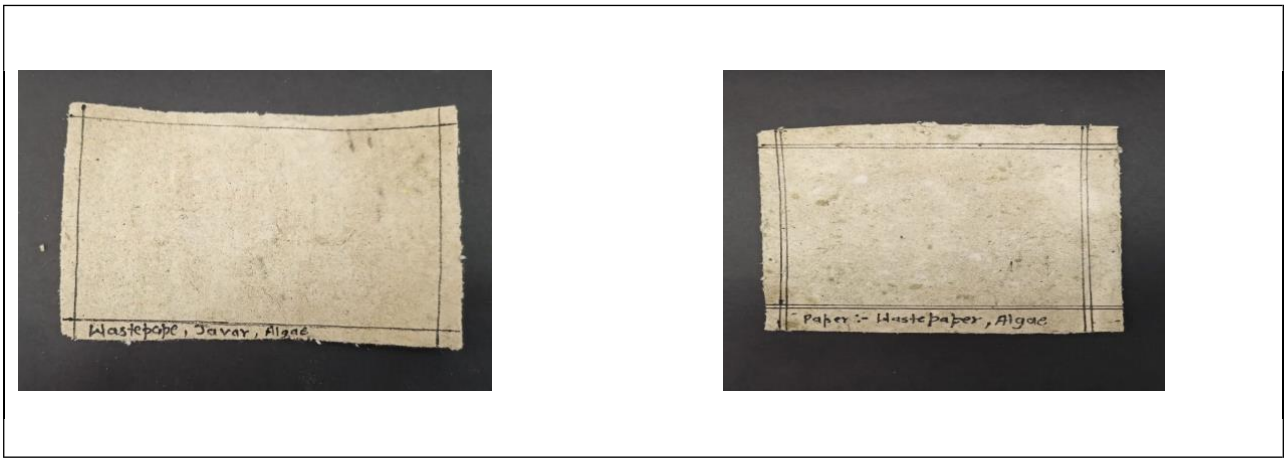

Figure 2: Different formulation of algal paper (*Pithophora oedogonia*)

6. DISCUSSION

While working with the substitutes for natural resources which can be used to make paper, many approaches were tapped and utilized. Moral *et. al.* in 2019 while working on *Ulva sp*., a green seaweed, with high abundance of holocellulose primarily α-cellulose, and a low percentage of acid-insoluble material and endorsed it as a promising raw material for papermaking due to its ease of processing, low energy consumption, and low chemical reagent concentration. We have utilized *Pithophora* spp. for the same purpose and found that with

A study by Kadam *et. al.* (2024) reveals that a balanced composition of 70% compost and 30% banana peels, along with drumstick powder and okra, produces the strongest handmade paper. Moral *et. al. in 2019 have* combined *Ulva spp.* with *Pinus pinaster*, *Ulva* sp. pulps provide paper sheets with good physical properties; surpassing the tear resistance of softwood fibers alone but in this above study they have utilized hydrogen peroxide and other chemicals.

We have used different natural ingredients like Aloe vera as conditioner, *Sapindus mukorossi* as detergent, *Triticum aestivum* power and bark glue of Acacia as binder etc. in order to minimize environmental concerns and to improve the quality of paper. They find this somewhat challenging in concern with decomposition in paper. Our

approach may give an efficient and well-planned measures to support and improve the industry with ecofriendly approach.

7. CONCLUSIONS

The application of algae as an unconventional raw material for the manufacture of cellulose in paper is an eco-friendly option for the preservation of the environment. Through the replacement of conventional raw materials with algae, the problem of excessive algal growth in water bodies and attendant issues of deforestation and land acquisition to produce paper can be reduced. The process of producing algal paper is economical, modifiable, and eco-friendly and thus an apt substitute for paper-based products. In addition to this, the findings of the study suggest favorable acceptance of algal paper across a wide diversity of participants and point towards widespread acceptance and integration of algal paper as a green substitute for paper products in the market. In general, the application of algae in papermaking presents a viable chance to manage pollution and encourage environmentally friendly practices in papermaking.

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