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Research Article

A CASE STUDY ON BIODEGRADABILITY OF NONWOVEN BAGS DISTRIBUTED IN THE NASIK CITY AS AN ALTERNATIVE TO PLASTIC BAGS

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ABSTRACT

After ban on plastic in Maharashtra state of India, different types of nonwoven bags were distributed as an alternative to plastic bags by shop owners. Under the ban, nonwoven polypropylene bags, which at first glance look like cotton bags, were not permitted. Permission was only for spun bond nonwoven bags made up of natural polymers like starch, baggase and ester bio-copolymer. Present study was on biodegradability of these nonwoven bags, widely distributed by shop owners in the city of Nasik. Samples of nonwoven bags were collected. Soil samples of landfills where these types of nonwoven bags were dumped were collected. Primary screening for identification of microorganisms was carried out. Consortiums of them were applied to check biodegradability of all nonwoven bags. In-situ method was also applied for three months. FTIR was the test used to find out functional groups of polymers present in the samples of nonwoven bags.

It was observed that the weight of some of the samples of nonwoven bags was slightly reduced after 3 months. Furthermore, no degradation was observed in the majority of samples. In situ method also found ineffective. For comparison, the nonwoven bags made up of natural polymer were also subjected for biodegradability. Within a month they completely degrade the natural polymer containing nonwoven bags. Similarly, soil burial method showed complete degradation.

INTRODUCTION

National Green Tribunal in Delhi NCR introduced a ban on disposable plastic like cutlery, bags and other plastic items amidst concerns over India's growing waste. But its effective implementation and enforcement emerged to be an issue. As a result, India continues to be top four producers of plastic waste in the world. [(1)] Plastic bags have become an essential part in our daily life as a crucial need and it is fact that plastics will never degrade and will remain on landscape. There are number of environmental issues caused by indiscriminate littering of plastic owing to unskilful recycling as well as reprocessing and nonbiodegradability. Therefore, ban on 'plastic' in the state of Maharashtra was implemented on different types of nonwoven bags were distributed as an alternative to plastic bags by vendors.

There are various types of nonwoven materials. Each type of nonwoven can be made from different types of fibres. The type of fibre determines whether a nonwoven bag is biodegradable or not. In most cases, (well over 90 % as of 2012) nonwoven bags are made up of spun bond polypropylene. Spun bond is a nonwoven type of fibre. Polypropylene is not biodegradable.

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Spun bond can be produced with biodegradable fibres. These fibres are over twice as expensive as polypropylene. [(2)]

Under the ban, nonwoven polypropylene bags looking similar to cotton bags were not permitted in the state. [(3)] The government had allowed the use of only spun bond nonwoven bags made up of natural polymers like starch, baggase and ester bio-copolymer (bonding polymer). Nonwoven materials are broadly defined as sheet or web structures bonded together by entangling fibre or filaments (and by perforating films) mechanically, thermally, or chemically. They are flat or tufted porous sheets that are made directly from separate fibres, molten plastic or plastic film. [(4)]

Present study was on biodegradability of these nonwoven bags, sold by vendors in the city of Nasik, Maharashtra. Samples of nonwoven bags were collected from shop vendors and chemists in city, used for distribution of medicines, grocery and garments. As per plastic management rules (PWM rules 2011), these bags were labelled 'compostable', if they are made from compostable material. If made of plastic, were labelled or marked 'recycled' as per IS: 14534:1998. [(5)] But it is observed that, on the collected bags such type of label was not present.

MATERIALS AND METHODS

1. Nonwoven bags distributed in the market by vendors.
2. A nonwoven bag made up of natural polymer.
3. Minimal medium: containing NH_4NO_3- 1g/lit, $MgSO_4.7H_2O$- 0.2 g/lit, K_2HPO_4-1 g/lit, $CaCl_2.2H_2O$-0.1 g/lit, KCl-0.15g/lit, Yeast extract-0.1 g/lit, $FeSO_4.6H_2O$- 1mg/lit, $ZnSO_4.7H_2O$ -1mg/lit, $MnSO_4$-1mg/lit.
4. St. Nutrient agar plates and slants
5. Soil samples from dumping areas where all types of domestic waste with plastic were dumped, compost mixture, and garden soil for soil burial method.
6. Requirements for bio chemicals for identification of organisms.

Sample Collection: 12 different unwoven bags were collected from grocery shops, textile market, and medical shops from Nasik city. Cut pieces of these bags of 25mm x 25mm sizes were prepared, labelled as 1 to 12, weighed and noted down.

In-situ method: Soil burial Method: This method involves the use of test samples (here nonwoven bag material) with particular measurement studied under natural environmental setting or under laboratory parameters. Garden soil which was rich in humus and compost were mixed with soil from landfills where unwoven bags and other domestic waste were dumped for years. Twelve beakers, each having 500 ml capacities were filled with the mixture of these soils. Each piece of unwoven bag separately buried at desired depth into the mixture. Moisture, PH and temperature of soil in each container were maintained appropriately throughout the experiment. They were checked throughout for first 15 days and then checked on alternate days for three months. Later, the samples were removed from the containers, washed and dried after which it was weighed.

Enrichment of Microorganisms: Few grams of soil dispersed around the pieces in beaker were collected after two weeks incubation in the soil burial method. It was further used for preparation of microbial consortia by enriching microorganisms in these soil samples in liquid media. In the process for enrichment of microorganisms, 12 flasks each containing different pieces of unwoven bags were mixed with synthetic minimal liquid media. Soil samples were inoculated. The only carbon sources in these media are pieces of the bags sampled. It was incubated in shaker for 8 days, at room temperature. [6] Later, the liquid media was inoculated on sterile nutrient agar plates, for isolation of microorganisms. They were identified on the basis of their cultural, morphological and biochemical characteristics.

Biochemical tests: The isolated cultures were subjected to standard biochemical tests such as Indole, Methyl red, Voges Proskauer test, Citrate utilization tests, to identify whether they utilize tryptophan which produces acid or alkali as end product and utilization of citrate as their sole source of carbon respectively. Other tests such as urease test, for detection of urease production. Catalase test used to determine the breakdown of hydrogen peroxide. Oxidase test used to test production of cytochrome oxidase. Nitrate test, for determination of formation of nitrite. Mannitol fermentation used to determine utilization of mannitol. Cellulose hydrolysis used to detect cellulase-degrading microorganisms also carried out. [7] Gelatine hydrolysis was carried out, to find gelatine liquefying organisms. [8] Triple sugar iron tests also performed to confirm results on fermentation of sugars. [9]

These microbial cultures were subjected to check biodegradability of unwoven plastic bag materials. In-vitro conditions were applied to check biodegradability of the collected nonwoven bags samples, by using liquid minimal media in flasks, wherein the components of the material in nonwoven bags were the only carbon source for microorganisms. Minimal media was used to focus on a specific group of organisms that can grow in the presence of minimum nutrients. It was incubated on shaker for 45 days, at room temperature. Later the samples were removed from the flasks, washed and dried after which it was weighed.

For a comparison purpose, the nonwoven bags made up of natural polymer also subjected for biodegradability by applying selective consortium developed similarly as above mentioned screening method.

Fourier Transform Infrared Spectrophotometer (FTIR) was the test used to find out functional groups of polymers, if present, in the samples of nonwoven bags. FTIR analysis is carried to check the carbonyl index. The carbonyl index is a measure of concentration of carbonyl groups such as acids, aldehydes, and ketones [10]. The plastic bags sample was found to dissolve in methanol, so a thin film of the sample was prepared by the following procedure:

- 2 g of the sample was allowed to dissolve in 10 ml methanol.
- Placed an IR crystal (KBr) window on top of a paper towel on a hot plate set at 40°C.
- 2–3 drops of the sample solution were deposited on the crystal window.
- The solvent was allowed to evaporate; thin film of the sample was left behind.

The thin film so obtained was placed in the IR beam and the IR spectrum was obtained.

RESULTS AND DISCUSSION

Total 11 isolates were finally selected to prepare consortia for degradation of plastic, while 11 isolates were selected for degradation of natural polymers. They were identified using Bergey's manual of systematic bacteriology. Majority of isolates identified were belonging to Pseudomonas, Micrococcus, Bacillus and Azotobacter genus as in Table 1 and 2.

In weight loss method, it was observed that the weight of 3 samples namely sample 1, 2 and 4 of nonwoven bags were slightly reduced after 3 months in In-vitro conditions. Furthermore, no change in the weight of pieces of bags was observed in case of samples 6 and 10 of nonwoven bags. Samples 8 and 9 showed complete degradation while incomplete degradation of samples 5, 11 and 12 was observed. Interestingly, increase in the weight of samples 3 and 7 were observed. (Table no. 3).

In situ method was found ineffective for the samples as described earlier. On other hand, for comparison purposes, the control sample of nonwoven bags made up of natural polymer also subjected for biodegradability by applying selective consortium, within a month they completely degrade the natural polymer containing nonwoven bags (figure 1 and 2).

Similarly, soil burial method (In-Situ) showed complete degradation of these samples.

Table 1 Biochemical tests for nonwoven bags degrading microorganisms

Isolate No.	Indole	Methyl Red	VP	Citrate	Oxidase	Catalase	TSI	Nitrate	Urease	Cellulose	Gelatine	Organism
1	-	-	-	-	-	+	A/A	+	-	+	+	Micrococcus
2	+	+	-	-	+	+	A/A	-	-	+	+	Bacillus
3A	+	-	-	-	-	+	A/A	-	-	+	-	Micrococcus
3B	+	+	-	-	-	+	A/A	-	-	+	-	Acetobacter aceti
3C-1	+	-	-	-	-	+	A/A	+	-	+	-	Acetobacter
3C-2	-	+	-	-	-	+	K/A	+	-	+	-	Microbacterium lacticum
4A	+	+	-	-	-	+	K/A	+	-	+	+	Micrococcus varians
4B	+	+	-	-	-	+	A/A	+	-	-	-	Microbacterium lacticum
5	+	-	-	+	+	+	A/A	+	-	+	+	Micrococcus
6A	-	-	-	-	+	+	K/NC	-	-	-	-	M.laylae
6B	-	+	-	+	-	+	A/A	-	-	+	-	Listeria denitrificans

Table 2 Biochemical tests for natural polymer degrading microorganisms

Isolate No.	Indole	Methyl Red	VP	Citrate	Oxidase	Catalase	TSI	Nitrate	Urease	Cellulose degradation	Gelatine hydrolysis	Organism
7A	+	+	-	+	+	+	K/A	-	-	+	-	Pseudomonas
7B	+	+	-	+	+	+	K/A	-	-	+	-	Bacillus lentus
9B	+	-	-	-	-	+	A/A	+	-	+	-	Bacillus
11A	+	+	-	+	+	+	K/A G	+	-	+	+	M.agilis
11Bi	+	-	-	-	-	-	A/A G	+	-	+	-	Bacillus acidocaldarius
11Bii	+	+	-	-	+	+	K/A G	+	-	+	+	Azotobacter
11C	+	+	-	-	+	+	K/A G	+	-	+	+	Bacillus
12A	+	+	-	-	-	+	K/A	-	-	-	+	M.agilis
12B	+	-	-	-	+	+	A/A G	+	-	+	-	M.roseus
12Dii	+	-	-	+	+	+	K/A G	+	-	+	+	Bacillus subtilis
A	-	-	-	+		+	K/A	+	-	+	+	Azotobacter vinelandii

+ Positive, - Negative

Alkaline slant/no change in butt (K/NC) i.e Red/Red = glucose, lactose and sucrose non-fermenter

Alkaline slant/Alkaline butt (K/K) i.e Red/Red = glucose, lactose and sucrose non-fermenter.

Alkaline slant/acidic butt (K/A); Red/Yellow = glucose fermentation only, gas (+ or -), H2s (+ or -)

Acidic slant/acidic butt (A/A); Yellow/Yellow = glucose, lactose and/or sucrose fermenter gas (+ or -), H_2S (+ or -).

Table 3 Results of biodegradability of Nonwoven bags material using weight loss method in In-vitro conditions

Nonwoven bags	Initial wt in gm	Weight after 3 months
Sample 1	0.05	0.046
Sample 2	0.05	0.043
Sample 3	0.01	0.019
Sample 4	0.04	0.03
Sample 5	0.08	0.063
Sample 6	0.04	0.04
Sample 7	0.08	0.084
Sample 8	0.04	Complete degradation
Sample 9	0.05	Complete degradation
Sample 10	0.07	0.07
Sample 11	0.06	0.03
Sample 12	0.08	0.05
Control Sample	0.07	Complete degradation

Fig 1 Samples of nonwoven bags after 15 days, when subjected for biodegradation in In- vitro condition.

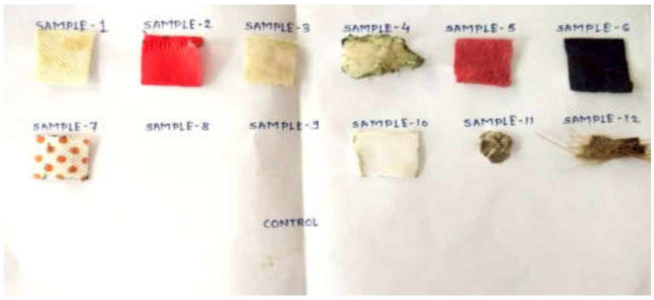
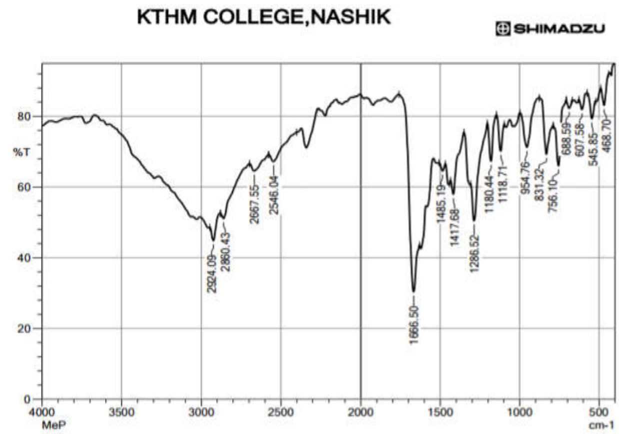


Fig 2 Samples of nonwoven bags after 30 days, when subjected for biodegradation in In- vitro condition.

Results of Fourier Transform Infrared Spectrophotometer tests (FTIR)

Overall studies suggested that sample no 1, 2, 5, 7, 8, 9, 11, and 12 shows similar absorption spectra. Absorption spectrum of sample 1 was as follows.



Graph 1 IR spectra of Sample 1

Table 4 FTIR analysis of Sample 1

Sample 1	
Absorption band (cm-1)	Functional group
756.10	CH_2-Rock
1118.71	CH-Bend
1180.44	CH_3-Rock
1286.52	CH-bend
1666.50	C=O Stretch

From above graph of IR spectra of sample no.1, it is suggested that peak at 1666.50 cm^{-1} represents C=O streching, 1286.52 $cm^{-1}$and 1118.71 cm^{-1} represents CH-bend and at 756.10 cm^{-1} represents CH_2-Rock. According to this functional group, sample content may be Polypropylene or LDPE (Low density polyethylene). Polythene & plastic are petroleum products where alkenes oxides are polymerized to form plastics such as polythene. Plastic is one of the few new chemical material which pose environmental problems, and was found in these bags.

CONCLUSION

Decomposition of the polymer depends on its chemical composition, which supports the growth of microorganisms in the form of nutrient sources. The starch-based polymer is favourable for microbial attack, and hydrolytic enzymes act on the polymer matrix to reduce their weight. Polymer made from starch or flax fibre shows greater biodegradability as compared to other synthetic polymers. In the present study consortia of polymer degrading microorganisms were prepared after their screening from soil samples, i.e. after isolation and enrichment. Common isolates identified were belonging to *Pseudomonas*, *Micrococcus*, *Bacillus* and *Azotobacter* genus. While checking biodegradability of the nonwoven bag samples, it was found that, out of twelve samples only two nonwoven bags collected from distributers in Nasik city, undergoes degradation by applied microbial consortia, which was similar to degradation of control sample made up of natural polymers, while other nonwoven bags remain nondegraded, indicative of presence of polyethylene in them, consequently should not be used as an alternative to the plastic bags. In support of the said conclusion FTIR was used. FTIR studies suggest presence of functional groups of polypropylene and LDPE in the majority samples of nonwoven bags. IR spectroscopy is unwavering, rapid and cost-effective. This application note describes several approaches to the measurement and analysis of IR spectra of typical polymer samples of the nonwoven bags.

Increase in the weight of samples 3 and 7 were observed. It was may be because of accumulation of certain substances in the material.

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