To assess the validity of Fourier transform infra-red spectroscopy (FTIR) for identifying polymer composition of spun bonded nonwoven bags

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ABSTRACT: As there is a ban on 'plastic' in Maharashtra state of India, different types of spun bonded non-woven bags were distributed/sold as an alternative to plastic bags by vendors. Under the ban, nonwoven polypropylene bags (who at first glance, look like cotton bags) were not permitted. The government had allowed the use of only spun bonded non-woven bags made up of natural polymer like starch, bagasse and ester bio-copolymer bonding polymer. The goal of this study was to thoroughly assess the validity of Fourier transform infra-red spectroscopy (FTIR) for identifying polymer composition of spun bonded nonwoven bags. Present study provides novel details that can help future studies avoid pitfalls, reduce confusion, and increase identification accuracy, providing clear ideas to identify spectra from HDPE and LDPE.

KEYWORDS: Fourier transform infra-red spectroscopy, High-density polyethylene, Low-density polyethylene, Natural polymer, Spun bonded non-woven bags

I. INTRODUCTION

The National green tribunal in Delhi NCR introduced a ban on a disposable plastic like cutlery, bags and other plastic items amid concern over India's growing waste[1] But its effective implementation and enforcement is an issue. As a result, India continues to be top four producers of plastic waste in the world. There are a number of environmental issues due to indiscriminate littering of plastic owing to unskillful recycling as well as reprocessing and non-biodegradability. Therefore, after the ban on 'plastic' in Maharashtra state of India, different types of non-woven bags were distributed/sold 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 fibers. The type of fiber determines whether a nonwoven is biodegradable or not. In most cases (well over 90 % as of 2012) non-woven bags are made up of spun bond polypropylene. Spun bond is the type of nonwoven and type of fiber. Polypropylene is not biodegradable. Spun bond bags can be produced with biodegradable fibers such as Bagasse and Easter bio-copolymer. These fibers are costlier over twice as expensive as polypropylene. Spun bonded fabrics are produced by depositing extruded, spun filaments onto a collecting belt in a uniform random manner followed by bonding the fibers[2]

Non-woven fabric is a fabric-like material made from staple fiber (short) and long fibers (continuous long), bonded together by chemical, mechanical, heat or solvent treatment. The term is used in the textile manufacturing industry to denote fabrics, such as felt [3]   Under the ban, nonwoven polypropylene bags (who at first glance, look like cotton bags) were not permitted in Maharashtra state. The government had allowed the use of only spun bonded non-woven bags made up of 'natural polymers' like starch, bagasse and ester bio-copolymer bonding polymer). The main goal of this work was to develop and test advanced techniques for the instant identification of different types of polymers in post-consumer plastics. In order to accomplish this task, infrared (IR) was applied for identifying polymers present in nonwoven spun bonded bags. This chemical technique is undoubtedly not new and is familiar but present study gives details that can help upcoming studies, avoid consequences, reduce mystification and at the same time increase identification accuracy. When IR radiation passes through a sample, some radiation is absorbed by the sample and some passes through (is transmitted). The spectrum of absorbed light represents a 'fingerprint' of the molecular structure of the sample. The usefulness of infrared spectroscopy arises because different chemical structures (molecules) produce different spectral fingerprints. FT-IR spectroscopy offers a simple, efficient and non-destructive method for identifying and distinguishing most plastic polymers, based on well-known infrared absorption bands representing distinct chemical functionalities present in the material. Structural isomeric polymers such as HDPE and LDPE are difficult yet important, to differentiate. LDPE had a unique characteristic (yet quite small) band at 1377 cm-1, representing a CH_3 bending deformation, suggesting that even these similar polymers can be distinguished using FT-IR spectra. This band is reportedly absent from HDPE. These polymers differ by the extent of branching with HDPE being a linear PE chain with minimal branching [4] Validation of ATR FT-IR to identify polymers of plastic marine debris, including those ingested by marine organisms, was already carried out.

[5][7]In the present study by using a simple method sample is prepared. Measurement times are typically below 1 minute. Therefore, FTIR spectroscopy saves time and cost when being compared to classical wet chemical methods[6] Some plasticized plastics products (e.g. PVC or nylon 11) will need to be extracted with a solvent (e.g. Methanol) first to remove the plasticizer. The following three model plastics were identified in this study, namely Low-density polyethylene (LDPE), High-density polyethylene (HDPE) and poly (methyl methacrylate).

II.   MATERIALS AND METHODS

Sample collection- After a ban on plastic bags, nine samples of different non-woven bags from different shops were collected. These bags were sold / distributed by vendors as non-woven bags (as an alternative to plastic bags) in Nashik city of Maharashtra. They were labelled as A (9), E (2), C (5), B (7), F (8), D (11), G (12), H (13) and I (mep).

Fig. 1 : Samples of Non -Woven bags

Film casting:

The pieces of nonwoven bags were found to dissolve in methanol.
A thin film of the sample was prepared as follows.
a)   Two grams of each sample was dissolved separately in 10 ml methanol in a screw capped bottle for 24-48 hrs.
b)   Placed an IR crystal (such as kbr) window on top of a paper towel on a hot plate set at 40 °C.
c)   2–3 drops of the sample solution were deposited on the crystal window.
d)   The solvent was allowed to evaporate, leaving behind the thin film of the sample.
e)   The thin film obtained, was placed in the IR beam and the IR spectrum obtained.
The spectrometer directs beams of IR at the sample and measures how much of the beam and at which frequencies the sample absorbs the infrared light.
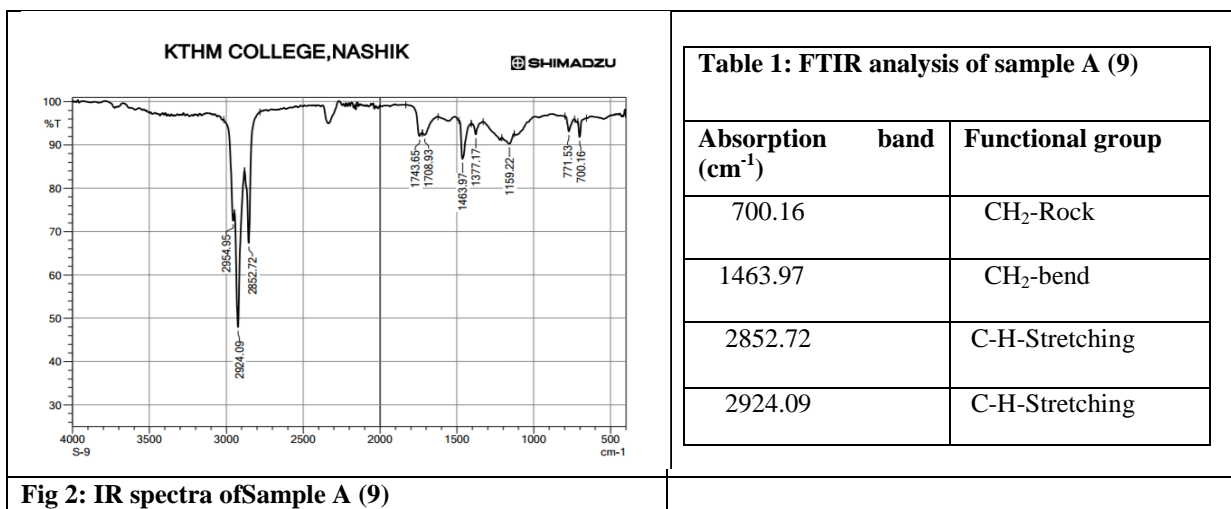The sample needs to be thin enough for the infrared light to transmit through, or a thin slice of the material must be removed.

FTIR is a technology that can identify chemicals using an infrared light source to measure absorption. First, the sample is exposed to different wavelengths of infrared light and the instrument measures which wavelengths are absorbed. Fourier Transform Infrared spectrophotometers are mainly used to measure light absorption of so-called mid-infrared light, light in the wavenumber range of 4,000 to 400 cm^{-1} (wavelengths 2.5 to 25 μm), in order to identify and quantify various materials.
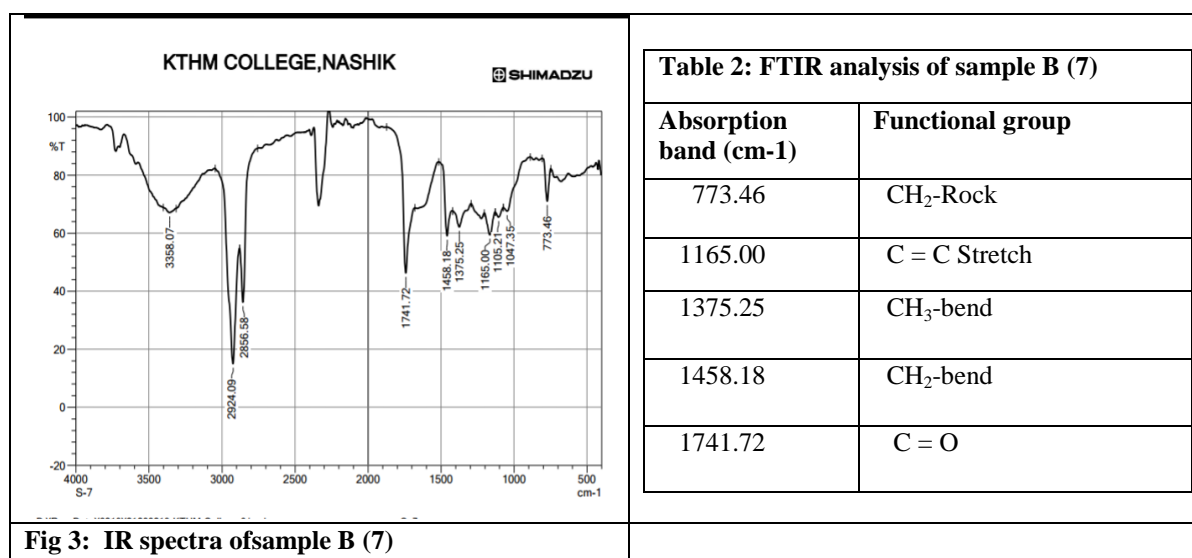
III RESULTS AND DISCUSSION

The primary use of the IR is to identify functional groups. Because the IR looks at the interaction of the EM spectrum with actual bonds, it provides a unique qualitative probe into the functionality of a molecule, as functional groups are merely different configurations of different types of bonds. Since most 'types' of bonds in covalent molecules have roughly the same energy, i.e., C=C and C=O bonds, C-H and N-H bonds they show up in similar regions of the IR spectrum. All organic functional groups are made of multiple bonds and therefore show up as multiple IR bands (peaks)

1: Graph- Sample A (9)

Table 1: FTIR analysis of sample A (9)

Absorption band (cm⁻¹)	Functional group
700.16	CH_2-Rock
1463.97	CH_2-bend
2852.72	C-H-Stretching
2924.09	C-H-Stretching

Fig 2: IR spectra ofSample A (9)

From above graph no 2, sample no. A (9), it is suggested that peak at 2924 cm⁻¹ and 2852.72 cm⁻¹ represents C–H stretching, at 1463cm⁻¹represents CH_2-bend and at 700.16 cm⁻¹CH_2-Rock. According to this functional group, sample content may be polypropylene (PP).

2: Graph - Sample B (7)

Table 2: FTIR analysis of sample B (7)

Absorption band (cm-1)	Functional group
773.46	CH_2-Rock
1165.00	C = C Stretch
1375.25	CH_3-bend
1458.18	CH_2-bend
1741.72	C = O

Fig 3: IR spectra ofsample B (7)

From above graph no.3 (sample no B.7), it is suggested that peak at 1741.72 cm⁻¹ represents C = O, 1458.18 cm⁻¹ represents CH_2-bend, at 1375.25 cm⁻¹CH_3-bend, at 1165.00 cm⁻¹ represents C = C stretch and at 773.46 cm⁻¹ represents CH_2-Rock.
According to this functional group, sample content may be polypropylene (PP) and LDPE (Low density polyethylene).
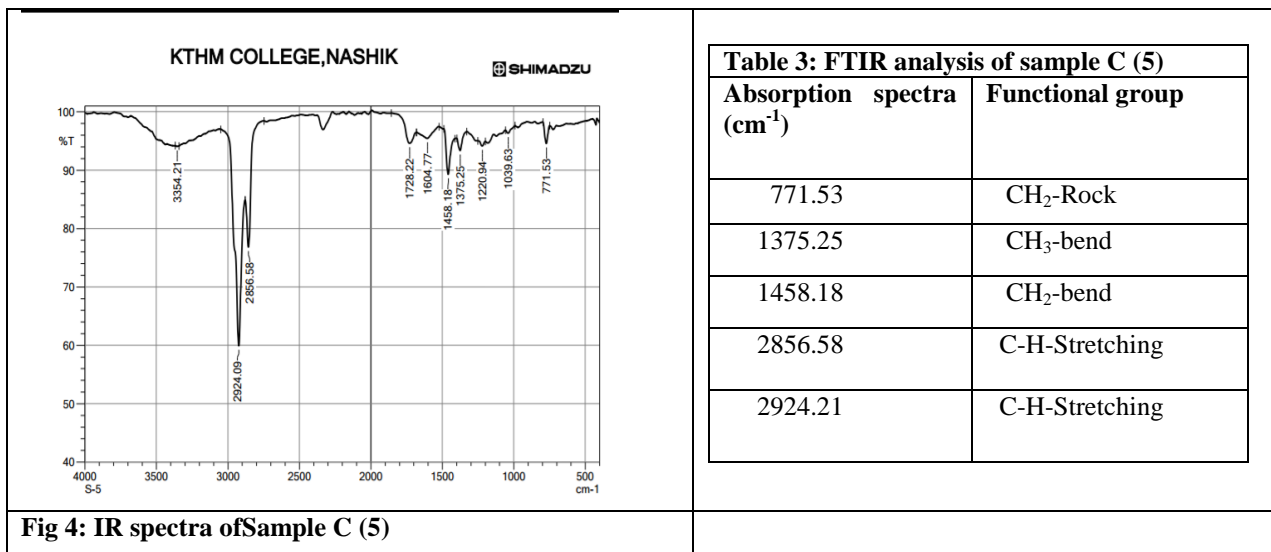
3: Graph - Sample C (5)

	Table 3: FTIR analysis of sample C (5)	
	Absorption spectra (cm^{-1})	Functional group
	771.53	CH$_2$-Rock
	1375.25	CH$_3$-bend
	1458.18	CH$_2$-bend
	2856.58	C-H-Stretching
	2924.21	C-H-Stretching

Fig 4: IR spectra ofSample C (5)

From above graph no.4, sample no. C (5), it is suggested that peak at 2924.21 cm^{-1} and 2856.58 cm^{-1} represents C-H stretching, 1458.18 cm^{-1} represents CH$_2$-bend, at 1375.25 cm^{-1}CH$_3$-bend, at and at 771.53 cm^{-1} represents CH$_2$-Rock. According to this functional group, sample content may be LDPE (Low density polyethylene).
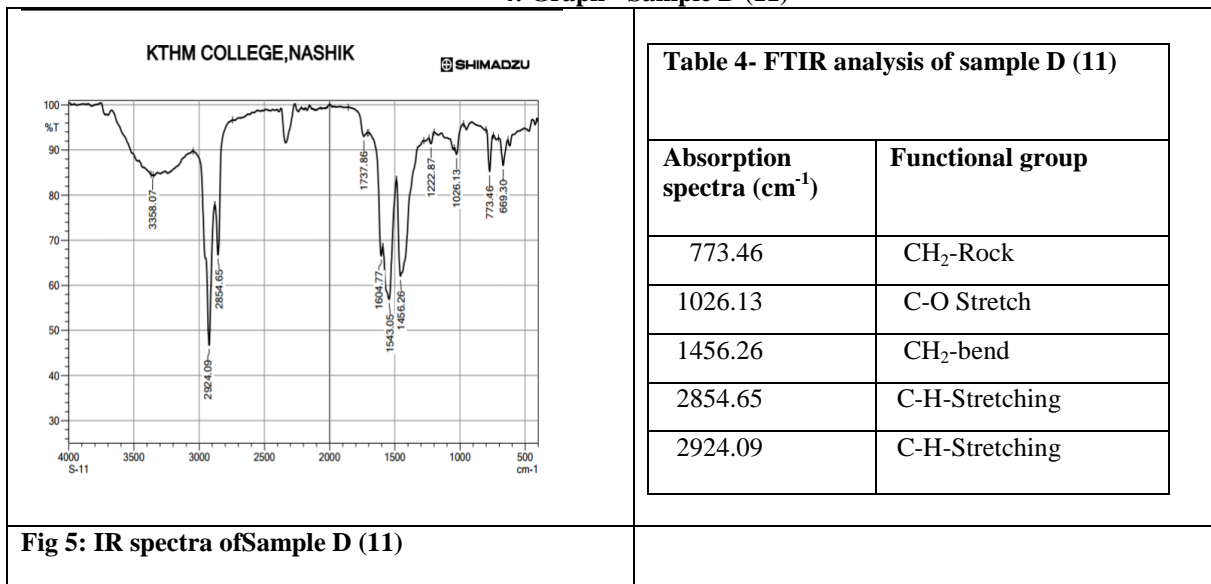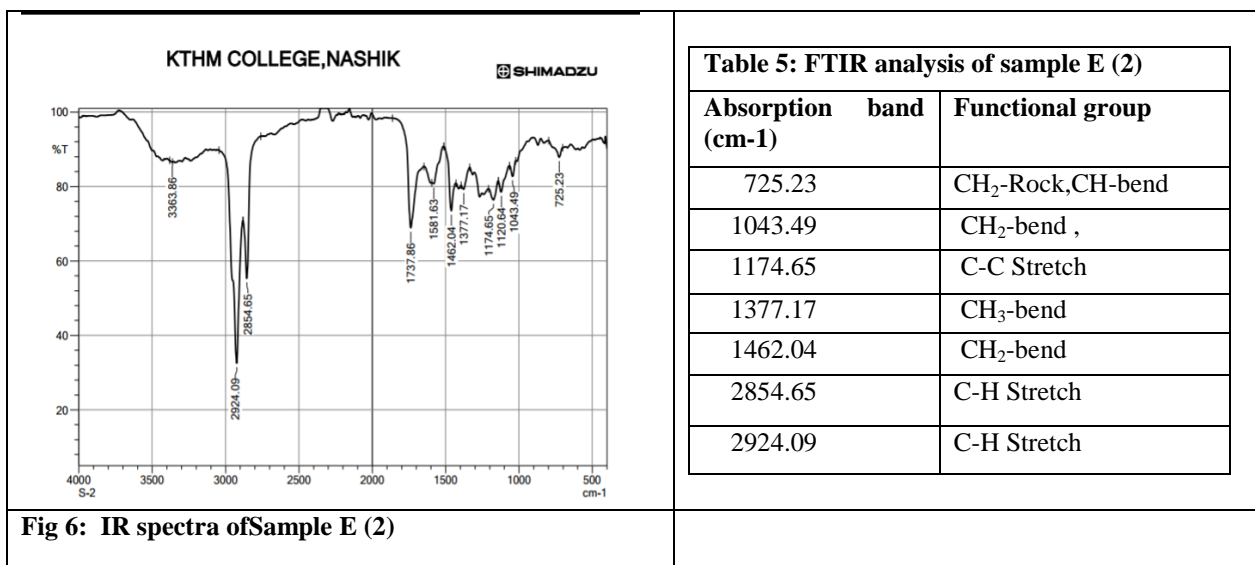
4: Graph - Sample D (11)

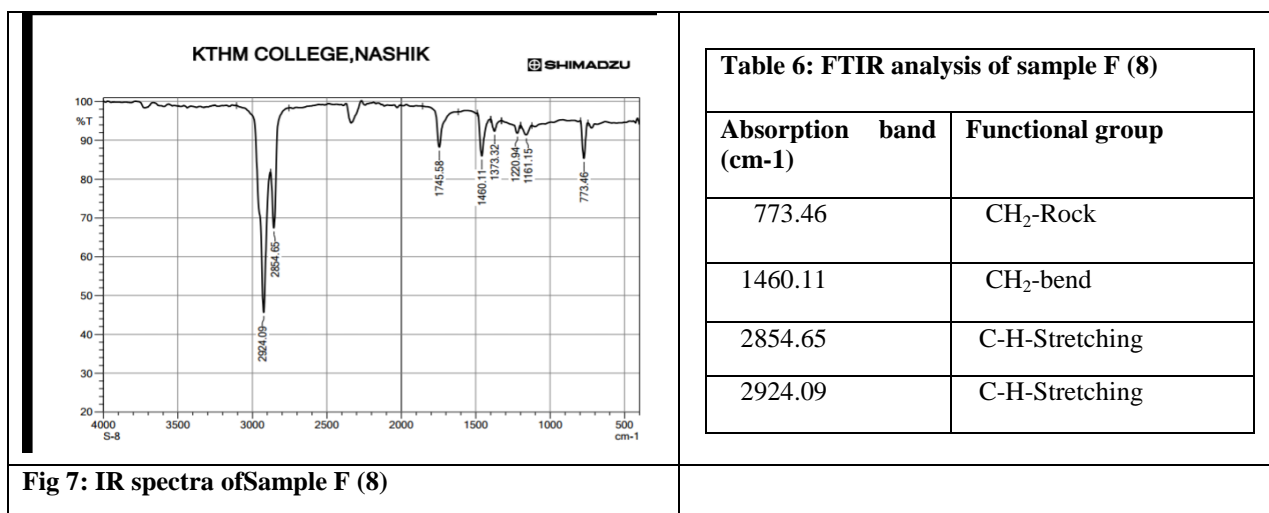|	Table 4- FTIR analysis of sample D (11)	
	Absorption spectra (cm^{-1})	Functional group
	773.46	CH$_2$-Rock
	1026.13	C-O Stretch
	1456.26	CH$_2$-bend
	2854.65	C-H-Stretching
	2924.09	C-H-Stretching

Fig 5: IR spectra ofSample D (11)

From above graph no.5, sample no. D (11), it is suggested that peak at 2924.21 cm^{-1} and 2856.58 cm^{-1} represents C-H stretching, 1456.26 cm^{-1} represents CH$_2$-bend, at 1026.13 cm^{-1} represents C-O stretch and at 773.46 cm^{-1} represents CH$_2$-Rock. According to these functional group, sample content may be LDPE (Low density polyethylene) or HDPE (high density polyethylene)

5: Graph - Sample E (2)

Table 5: FTIR analysis of sample E (2)	
Absorption band (cm-1)	**Functional group**
725.23	CH_2-Rock,CH-bend
1043.49	CH_2-bend ,
1174.65	C-C Stretch
1377.17	CH_3-bend
1462.04	CH_2-bend
2854.65	C-H Stretch
2924.09	C-H Stretch

Fig 6: IR spectra ofSample E (2)

From above graph no.6, sample no. E (2), it is suggested that peak at 2924.21 cm^{-1} and 2856.58 cm^{-1} represents C-H stretching, 1462.04 cm^{-1} and 1043.49 cm^{-1} represents CH_2-bend , at 1377.17 cm^{-1} represents CH_3-bend, at 1174.65 cm^{-1} represents C-C stretch and at 725.23 cm^{-1} represents CH_2-Rock . According to this functional group, sample content may be LDPE (Low density polyethylene) or HDPE (high density polyethylene).
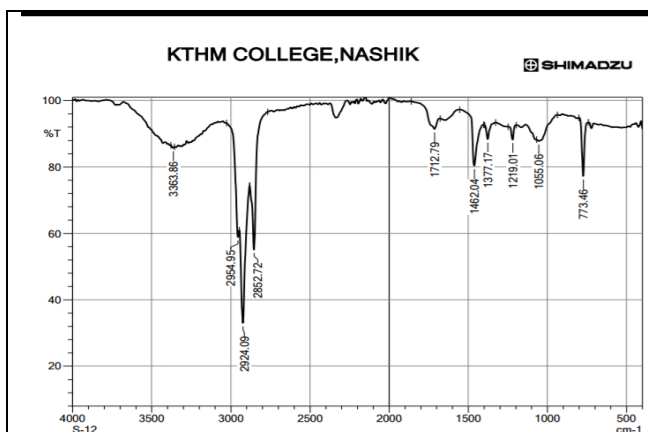
6: Graph - Sample F (8)

Table 6: FTIR analysis of sample F (8)	
Absorption band (cm-1)	**Functional group**
773.46	CH_2-Rock
1460.11	CH_2-bend
2854.65	C-H-Stretching
2924.09	C-H-Stretching

Fig 7: IR spectra ofSample F (8)

From above graph no.7, sample no F (8), it is suggested that peak at 2924.21 cm^{-1} and 2856.58 cm^{-1} represents C-H stretching, 1460.11 cm^{-1} represents CH_2-bend and at 773.46 cm^{-1} represents CH_2-Rock. According to this functional group, sample content may be LDPE (Low density polyethylene)
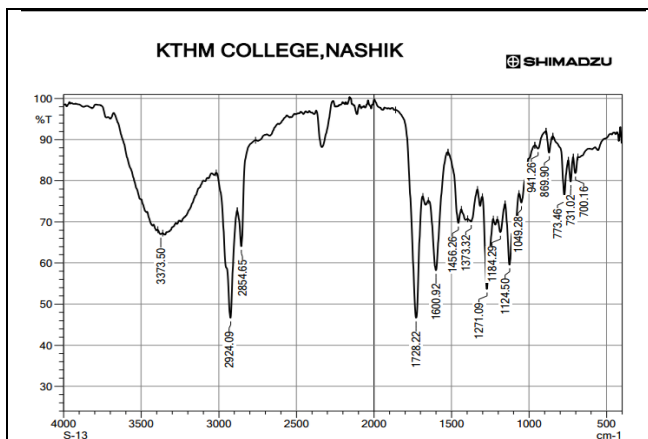
7: Graph - Sample G (12)

KTHM COLLEGE,NASHIK	Table 7: FTIR analysis of sample G (12)	
	Absorption band (cm-1)	**Functional group**
	773.46	CH_2-Rock
	1462.04	CH_2-bend
	2852.72	C-H Stretch
	2924.09	C-H Stretch
Fig 8: IR spectra ofSample G (12)		

From above graph no.8, sample no. G (12), it is suggested that peak at 2924.09 cm^{-1} and 2852.72 cm^{-1} represents C-H stretching, 1462.04 cm^{-1} represents CH_2-bend and at 725.23 cm^{-1} represents CH_2-Rock. According to this functional group, sample content may be LDPE (Low density polyethylene).
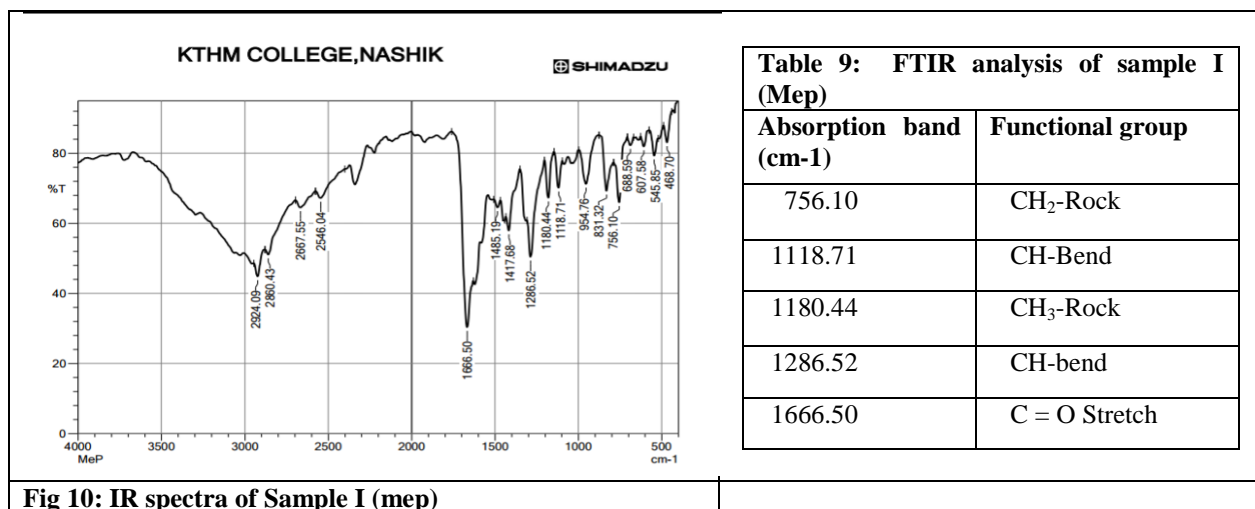
8: Graph- Sample H (13)

KTHM COLLEGE,NASHIK	Table 8 - FTIR analysis of sample H (13)	
	Absorption band (cm^{-1})	**Functional group**
	731.02	CH_2-Rock
	941.26	CH-bend
	1184.29	CH_3-Rock
	1373.32	CH_3-bend
	1456.26	CH_2-bend
	1728.22	C=O stretching
Fig 9: IR spectra ofSample H (13)		

From above graph no. 9, sample no. H (13), it is suggested that peak at 1728.22 cm^{-1} represents C=O stretching 1456.26 cm^{-1} represents CH_2-bend , at 1373.32 cm^{-1} represents CH_3-bend, at 1184.29 cm^{-1} represents CH_3-Rock, at 941.26 cm^{-1} represents CH-bend and at 731.02 cm^{-1} represents CH_2-Rock. According to these functional groups, sample content may be Poly (methyl methacrylate).

9: Graph -Sample I (mep)

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Table 9: FTIR analysis of sample I (Mep)	
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

Fig 10: IR spectra of Sample I (mep)

From above graph no.10, sample no. I (mep), it is suggested that peak at 1666.50 cm^{-1} represents C = O stretching, 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).

III. CONCLUSION

The studies of sample no E (2), sample no C (5), sample no B (7), sample no F (8), sample no A (9), sample no D (11) and sample no G (12) suggested that peak at 2924.09 cm^{-1}. Represents the formation of C – H Stretch, at 773.46 cm^{-1} represents CH_2 Rocks, at 1100 cm^{-1} represents CH-bend and CH_3 Rock, at 1710–1750 cm^{-1} represents formation of ketone or aldehyde C=O groups; and at 1400 cm^{-1} represents CH_2.

The sample H (13) Shows CH_2-Rock at 731.02 cm^{-1}, CH-bend at 941.26 cm^{-1}, CH_3-Rock at 1184.29 cm^{-1} CH_3 bend 1373.38 cm^{-1}, CH_2 bend 1456.26 cm^{-1}, C = O stretching at 1728.22 cm^{-1}.

From above graph overall studies suggested that, spun bonded non-woven bag sample number A (9), E (2), C (5), B (7), F (8), D (11), G (12), and I (mep) shows similar absorption spectra. These absorption spectra detect the functional group present in the sample. According to these functional groups, sample content may be Polypropylene (PP), LDPE (Low density polyethylene), and HDPE (high density polyethylene).

Only the sample H (13) shows different absorption spectra than others. The sample H (13) content may be poly (methyl methacrylate).

NOMENCLATURE

CH: Methylidyne
CH2: Methylene and belongs to the general compound category of Alkenes.
CH3: A methyl group is an alkyl derived from methane.

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