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Original Research Article

Qualitative Determination of Virgin and Recycled Plastic Used for Drinking and Storing Foodstuff: An Analytical Study Using SEM/EDX

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ABSTRACT

Introduction: Plastics have become an integral part of life. Their usage pattern in daily life in sectors such as furniture, house wares, mechanical, engineering, aviation, floor sheet, lamination, biomedical etc. Improper disposal and use of recycled plastic products are significant source of environmental pollution, Packaging material has many toxic heavy metals such as cadmium, chromium, lead, mercury etc. that contaminates the environment and cause public health problem.

Objectives:

The study was done on the physical state, odour, clarity of leachate, chemical characteristics of the plastic samples.

To estimate the presence of heavy metals content like cadmium, chromium, iron, arsenic,

Materials and methods: A detailed study of heavy metals in virgin and recycled plastic was conducted by using SEM/EDX Scanning electron microscopy with energy dispersive X-ray spectroscopy. Ten samples of virgin plastics were collected from 4 zones of Lucknow district. Analysis of Functional Groups was done by FTIR.

Result: Cadmium was found in both virgin as well as recycled plastics in amount of 0.11 -0.43 ppm. The maximum amount of Cr was 0.1 ppm and minimum was 0.01 ppm. Iron ranges from 0.02 ppm - 2.4 ppm and the maximum amount of arsenic was found to be 0.98 ppm and minimum was 0.03 ppm.

Conclusion: Based on our study, we can conclude that the recycled plastics products are not recommended for use in product intend to come in contact with foodstuff.

Keywords: Recycled Plastic, Heavy Metals, Human Health.

INTRODUCTION

This word plastic comes from the Greek word “plastikos”, which means ‘able to be molded into different shapes’ [1] or processed into a variety of forms, including solid objects, films and filaments. Plastics are synthetic substances produced by chemical reactions. Plastic has many properties, having the ability to be shaped by the application of reasonable amount of heat and pressure or some other form of force, which has made it a raw material of choice for manufactures of plastic bags and packing materials. Cost of production, lightweight, strength, easy process of manufacture, and availability are few of the properties. Plastic material is any of a wide range of synthetic or semi-synthetic organic solids that are moldable.

Plastics are formed by polymerization; polymerization is the process by which individual units of similar or different

molecules ("mers") combine together by chemical reactions to form large or macromolecules in the form of long chain structures. Plastics are typically organic polymers of high molecular mass, but they often contain other substances. They are usually synthetic, most commonly derived from petro- chemicals, but many are partially natural. Plastics are formed by polymers that determine the plastic type and additives (e.g. antioxidants, stabilizers, plasticizers, flame retardants, and catalysts) that enable processing or give the plastic its desired properties in a certain application [2] and having the ability to be shaped by the application of reasonable amount of heat and pressure or some other form of force. These properties arise from their molecular structure. There is nothing wrong with plastic as a material. The current growth rate in Indian polymer consumption (16% p.a.) is clearly higher than that in China (10% p.a.) and many other key Asian countries. [3-5] The capacities built in most of the segments of this industry coupled with inherent. Almost all plastics are made from petroleum, except a few experimental resins derived from corn and other organic substances. The vast majority of these polymers are based on chains of carbon atoms alone or with oxygen, sulfur, or nitrogen as well.

There are mainly two types of Plastics Thermoplastics and Thermosetting Plastics. **Thermoplastics** - These plastics are those, which once shaped or formed, can be softened by the application of heat and can be reshaped repeatedly, till it loses its property. Example: Polyethylene, Polypropylene, Nylon, Polycarbonate etc.

Thermosetting Plastics - These plastics are those, which once shaped or formed, cannot be softened by the application of heat. Example: Phenol formaldehyde, Urea Formaldehyde, Melamine Formaldehyde, Thermosetting Polyester etc.

The plastics we use today are made from inorganic and organic raw materials, such as carbon, silicon, hydrogen, nitrogen, oxygen and chloride. **Other types of Plastics are** Parkesine Bakelite **Polystyrene** Polyvinyl chloride, Nylon, Rubber, Synthetic rubber, Polyethylene Terephthalate (PETE OR PET), High density polyethylene (HDPE), **Polypropylene (PP) etc.** Many big cities (e.g. Mumbai, Bangalore) and some of the states (e.g. Delhi, Maharashtra, Uttar Pradesh) have already banned the use of thin plastic bags. [6] The plastics we use today are made from inorganic and organic raw materials, such as carbon, silicon, hydrogen, nitrogen, oxygen and chloride. Thermoplastics contribute to the total plastic consumption by roughly 80%, and are used for typical plastics applications such as packaging but also in non- plastics applications such as textile fibres and coatings. [7] **Uses of plastic include:** - Pipes, Floor coverings, cable insulation, roofing sheets, packaging foils, bottles and medical products, car interiors, soft drink and water bottles, jars, clamshell packages like cooking containers or trays snacks food packages and cereal box liners, Plastic trash bags grocery sacks, tubing, agricultural films and lumber etc. Polymer chemists utilize only 8 of the more than 100 known elements to create thousands of different plastics, [8] these eight elements being hydrogen, carbon, nitrogen, oxygen, fluorine, silicon, sulphur and chlorine. More than 50 different families of plastics are in commercial use today, and each may have dozens of sub-type and variations.

Improperly disposed plastic materials are a significant source of environmental pollution, potentially harming life. Man has simply not put the plastic to the right use/ or using it without taking proper care of norms related to usage. Improperly disposed plastic materials are a significant source of environmental pollution, potentially harming life. In addition, the burning of polyvinylchloride (PVC) plastics produces persistent organic pollutants known as furans and dioxins. [9] Several plastics additives and monomers are hazardous to human health and the environment. Examples of properties for some additives and monomers are: toxic for

reproduction (e.g. di (2-ethylhexylethyl-hexyl) phthalate (DEHP) and bisphenol A), carcinogenic (e.g. vinyl chloride, acrylonitrile, benzene and 1, 3-butadiene), allergenic (e.g. formaldehyde, acrylonitrile, toluene diisocyanate (TDI) and methyl methacrylate), mutagenic (e.g. benzene, phenol, and 1, 3- butadiene), high chronic toxicity (e.g. benzene) and environmentally hazardous with long term effects (e.g. pentabromodiphenyl ether (PeBDE), acrylonitrile). Brominated flame retardants and phthalates used in plastic products are widely spread in the environment today. [10,11] The plastic components have been found in water, [12,13] foods, [14] indoor air [15] and house dust. [16]

Availability of some heavy metals in plastics:

1. **Copper**

Higher copper content in food and drinking water may contribute to the development of severe liver damage of infant. Inhalation of copper dust and fumes result in irritation of upper respiratory track. Ulceration, perforation of the nasal septum and discolouration of skin and hair.

2. **Cadmium**

The acute manifestations observed in men are gastrointestinal disturbances following injection and chemical pneumonitis .Inhalation of cadmium compound at concentration above 1 mg/m^3 in air for 8 hour of higher concentration for shorter period may lead chemical pneumonitis and severe cases of pulmonary disease.

3. **Chromium**

Sufficient exposure to specific hexavalent chromium compound has been associated with an increase risk of lung cancer. Over exposure of chromium cause dermal nephrotoxicity and can result in necrosis.

4. **Lead**

Lead is the heavy metal enters the body through inhalation or ingestion the biological effect are same. Lead toxicity has larger deficit in psychometric intelligence, score speech and language processing.

Site Selection and Sample Collection

Ten samples of virgin plastics have been collected from 4 zone of Lucknow. And one is collected from center of Lucknow. In each zone 2 samples of virgin plastics were taken. The selected study area includes virgin and recycled plastic sample. These zones are Gomtinagar, Rajajipuram, Jankipuram, Southcity and Kesarbagh. Five samples of recycle plastic have been collected from five different area of Lucknow-Chinhat, Talkatora, Shaktinagar, Eldeco and Rakabgunj (table 1).

Table 1: Showing virgin plastics and recycled plastics with their colour and sample details.

S.no.	Sample	Colour	Sample detail		
			Class	Code	Location
1.	Pepsi	White	Virgin	V1	Gomti Nagar
2.	Thums up	White	Virgin	V2	Gomti Nagar
3.	Sprite	Green	Virgin	V3	Rajajipuram
4.	Fanta	White	Virgin	V4	Rajajipuram
5.	7 up	Green	Virgin	V5	Jankipuram
6.	Slice	White	Virgin	V6	Jankipuram
7.	Mirinda	White	Virgin	V7	Southcity
8.	Kenley	White	Virgin	V8	Southcity
9.	Coca – cola	White	Virgin	V9	Kesarbagh
10.	Dew	Green	Virgin	V10	Kesarbagh
11.	Pipe	Orange	Recycle	R1	Chinhat
12.	Bucket	Maroon	Recycle	R2	Talkatora
13.	Tub	Green	Recycle	R3	Shaktinagar
14.	Wire	Black	Recycle	R4	Eldeco
15.	Container	White	Recycle	R5	Rakabgunj

MATERIALS & METHODS

Change in physical state, odour, clarity of Leachate and analysis of Heavy Metals, Analysis of Shape and Chemical Characteristics by SEM/EDX, Analysis of Functional Groups by FTIR and Preparation of Leachate tests were done.

1. Preparation of Leachate:

The plastics pieces of 5x5cm were washed thoroughly with distilled prior to leach ability test. Double distilled water, acetic acid (3%), were used as the simulated solvent for physio-chemical test. Pieces of 1 cm surface area were exposed to 2 ml of stimulant (1 cm /2 ml of stimulant) in beaker at 60^{o}C for 2 hour in microwave oven. A blank (stimulant without test pieces sample) was run parallel by keeping the stimulants in the beaker in identical manner.

2. Analysis of Heavy Metals:

Procedure

Took 5x5 cm size of plastic. Washed thoroughly double distilled water. Cutting of plastics by blade and 1 gm. sample of plastics had taken in conical flask, then took 10 ml acid mixture of concentrated nitric acid and per chloric acid 3:1 ratio, Digested it on hot plate in the fuming chamber at 90-100^{o}C till the solution become transparent or clear white, then cooled it then diluted it with 0.1 N HNO3 (6.25 ml HNO3+93 ml distilled water=0.1 N HNO3).Filtered by watman filter paper and the solution of 25 ml maintained. The sample was ready to use analysis under Atomic Absorption Spectrophotometer.

3. Analysis by SEM/EDS:

Sample Preparation

Cutting of each sample into small pieces 1 mm, then washed with double distilled water. Kept them into aluminum foil, after drying in oven for 4 to 5 hours at 60^{o}C placed them in desecrator for 2 hours and the sample was ready for analysis.

Procedure

Samples were taken from aluminum foil stub with the help of carbon tape. A very thin film of gold and palladium was deposited on the surface of the sample to make them electricity conductive using vacuum coating unit. This extremely fine coating was done through the evaporation of Au-Pd plates under inert atmosphere. These samples mounted on the electron micro pore stubs. The SEM-EDS analysis was carried out with the help of a computer controlled field emission SEM (JOEL JSM-6330f, JOEL Ltd) equipped with a WVEX-EDX detection system to determine shape and size of the sample.

4. Analysis of the Funtional Groups by FTIR:

Sample Preparation

Each plastics sample washed thoroughly with double distilled water. Dried them in oven for 4 to 5 hour at 60^{o}C, then each sample scratch by blade on form powdery texture then kept them into aluminum foil, placed in desiccators for 2 hours and the sample was ready for analysis.

Procedure:

Samples were taken from the aluminum foil. Sample mixed with KBr (15 sample and 99% KBr) with the help of pistil and motor and then pellet is formed for analysis in FTIR.

RESULT & DISSCUSSION

A detailed study of Virgin and Recycle Plastics conducted in laboratory with advanced instruments. Relevant analyses of this study and results are presented below: (table 2).

Table 2: Showing virgin plastics and recycled plastics with their colour and sample details

S. No	TEST CARRIED OUT	INFERENCE
1.	Physical state of material before and after studies (requirement :no change)	No change
2.	Smell of the simulated solvent (requirement : odourless)	Odourless
3.	Clarity and color of the simulated solvent (requirement: should be Clear and colorless).	Clear and colorless

AAS analysis of heavy metal in virgin and recycled plastic:

AAS plastics analysis reveals that Cadmium, Chromium, Iron and Arsenic were presented in virgin plastics and recycled plastics.

1. Cadmium

Ca presented in only recycled plastics R1, R2, R3 and R4 Cadmium is found in both virgin as well as recycled plastics. The result shows that some plastics samples of virgin plastics do not contain cadmium V1, V9. While other samples of virgin plastics V2, V3, V4, V5, V6, V7, V8, V10 show cadmium between 0.06-0.75 ppm. The sample of recycle plastics contains cadmium in amount of 0.11 -0.43 ppm. It is clearly indicated that recycle plastic had much more amount of cadmium in them figure shows the comparison between both types of plastic.

2. Chromium

Chromium is found all samples virgin as well as recycle except V10.The maximum amount of Cr is 0.1 ppm and minimum is 0.01 ppm. Figure no clearly compares the amount of Chromium in both sample and shows recycle high amount of Chromium then virgin.

3. Iron

In virgin plastics their range from 0.02 ppm -2.4 ppm virgin plastic V1 shows least amount of iron while V2 shows high amount of iron. Recycle plastic sample R1 had least amount of Fe 0.67 and R3 .94.The result show much amount of Fe in recycle plastic in comparison to virgin plastic figure clearly shows comparison in both plastics.

4. Arsenic

Arsenic is found all samples virgin as well as recycle. The maximum amount of arsenic is 0.98 ppm and minimum is 0.03 ppm.

Result of SEM/EDX

In SEM/EDX analysis of virgin and recycled plastics structure and chemical composition reveal that Carbon and Oxygen compound were abundant in both virgin and recycled plastics samples is. Most intriguining feature is the presence of Titanium (Ti) recycled plastics sample R4.Si found in all recycled plastics sample. All virgin plastics samples have not formed Si, Al, Ti, and Mg. Zr presented in virgin plastics V2, V6, V7, V8, and recycled plastics R3 and R5. Pt presented in V2, V3, V7, V9, V10 and R2 (table 3).

Table.3. is showing chemical characteristics of samples of virgin and recycled plastics, (+) present, (-) not present using FTIR.

Code	C	O	Zr	Si	Al	Mg	Pt	Ca	Ti	Cl	K
V1	+	+	-	-	-	-	-	-	-	-	-
V2	+	+	+	-	-	-	+	-	-	-	-
V3	+	+	-	-	-	-	+	-	-	-	-
V4	+	+	-	-	-	-	-	-	-	-	-
V5	+	+	-	-	-	-	-	-	-	-	-
V6	+	+	+	-	-	-	-	-	-	-	-
V7	+	+	+	-	-	-	+	-	-	-	-
V8	+	+	+	-	-	-	-	-	-	-	-
V9	+	+	-	-	-	-	+	-	-	-	-
V10	+	+	-	-	-	-	+	-	-	-	-
R1	+	+	-	+	+	-	-	+	-	+	-
R2	+	+	-	+	-	+	+	+	-	+	+
R3	+	+	+	+	-	-	-	+	-	-	-
R4	+	+	-	+	+	+	-	+	+	-	+
R5	+	+	+	-	-	-	-	-	-	-	-

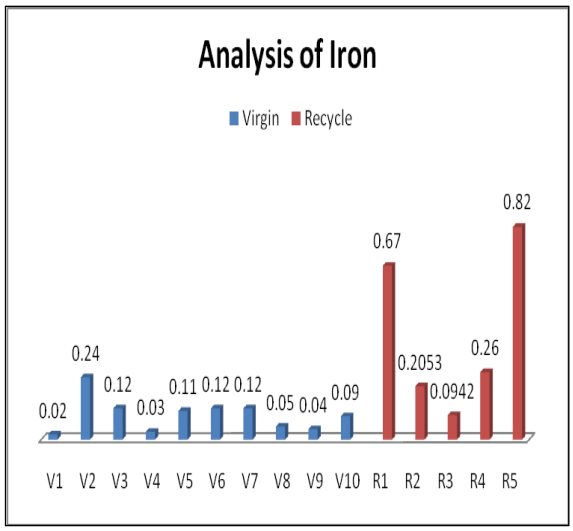

Fig: 1 Showing the amount of Iron in virgin and recycled plastic.

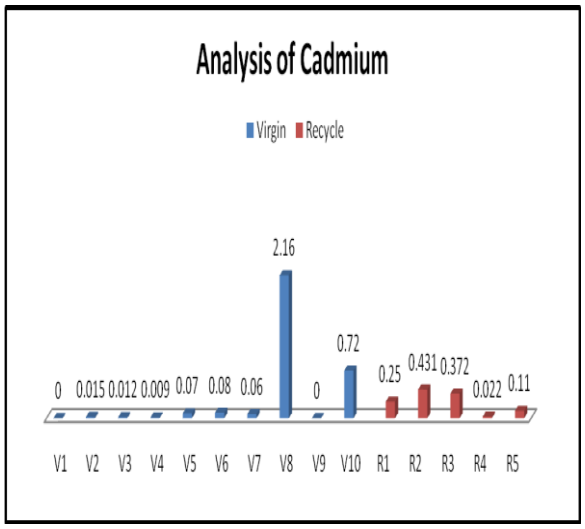

Fig: 2 Showing the amount of Cadmium in virgin and recycled plastic.

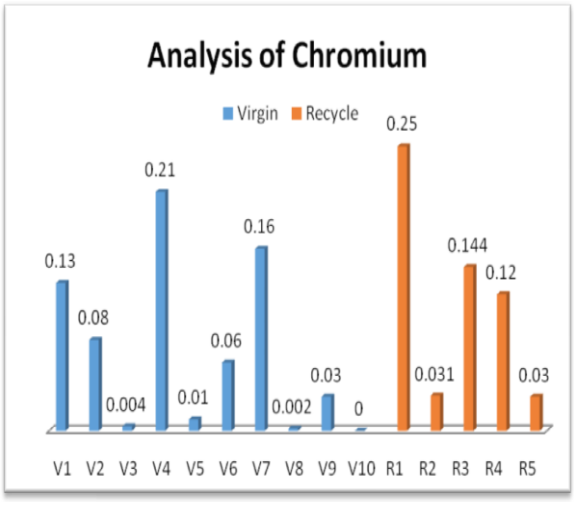

Fig: 3 Showing the amount of Chromium in virgin and recycled plastic

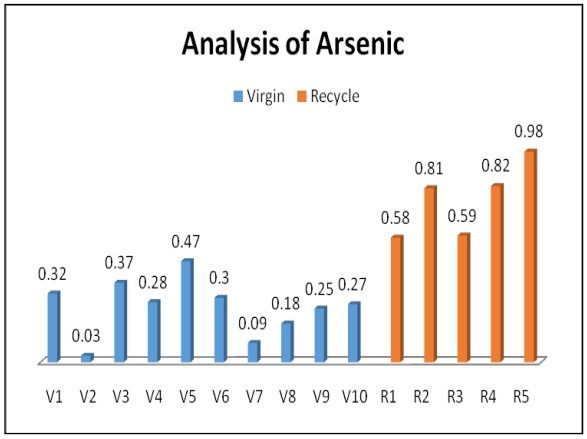

Fig: 4 Showing the amount of Arsenic in virgin and recycled plastic.

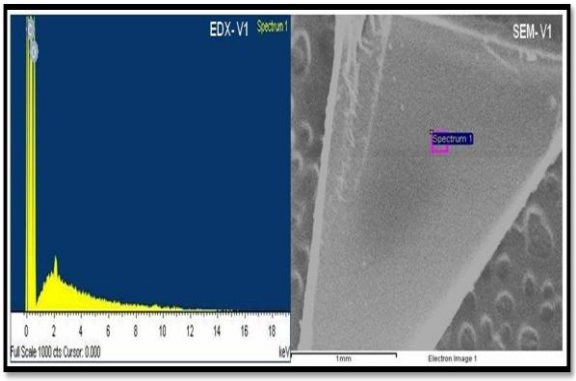

Fig: 5 SEM and EDX Scan of Virgin Plastic Sample (VI)

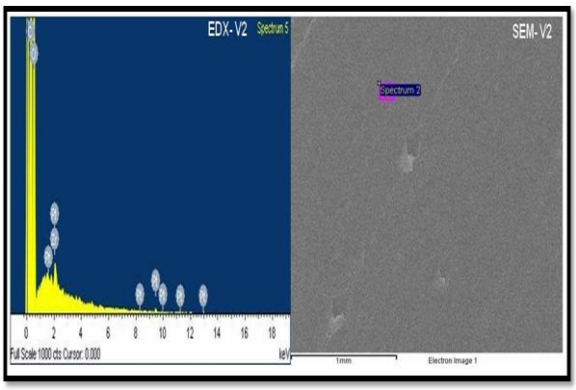

Fig: 6 SEM and EDX Scan of Virgin Plastic Sample (V2)

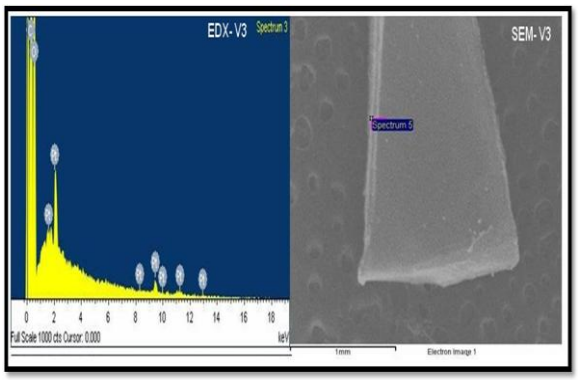

Fig: 7 SEM and EDX Scan of Virgin Plastic Sample (V3)

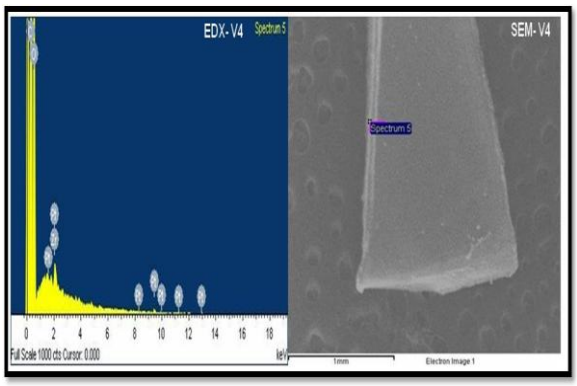

Fig: 8 SEM and EDX Scan of Virgin Plastic Sample (V4)

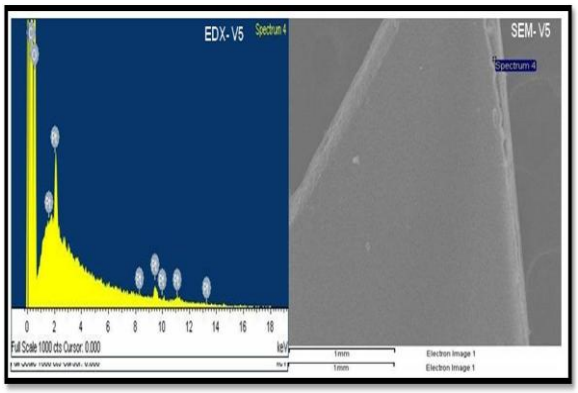

Fig: 9 SEM and EDX Scan of Virgin Plastic Sample (V5)

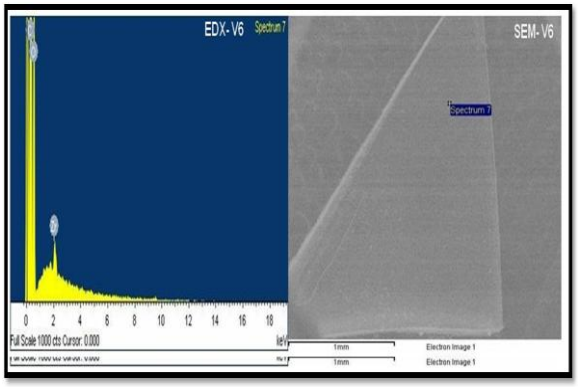

Fig: 10 SEM and EDX Scan of Virgin Plastic Sample (V6)

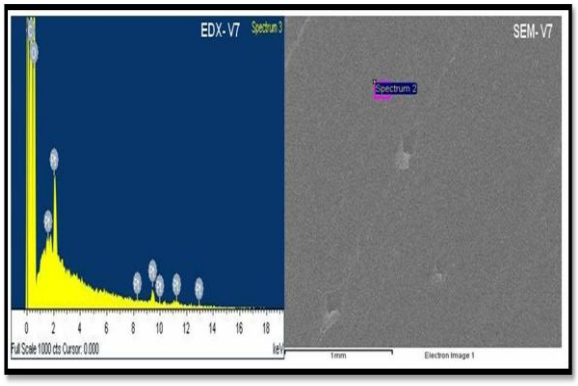

Fig: 11 SEM and EDX Scan of Virgin Plastic Sample (V7)

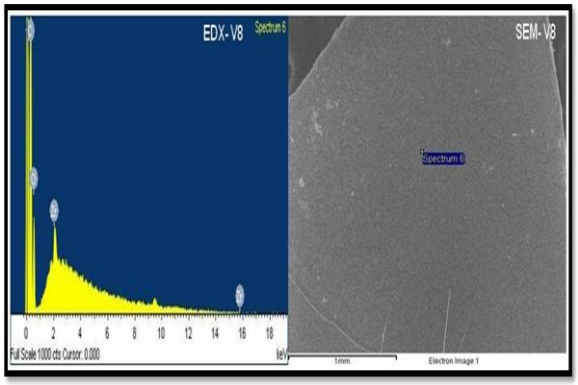

Fig: 12 SEM and EDX Scan of Virgin Plastic Sample (V8)

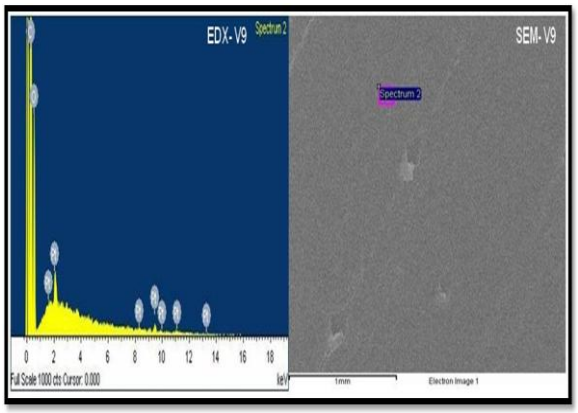

Fig: 13 SEM and EDX Scan of Virgin Plastic Sample (V9)

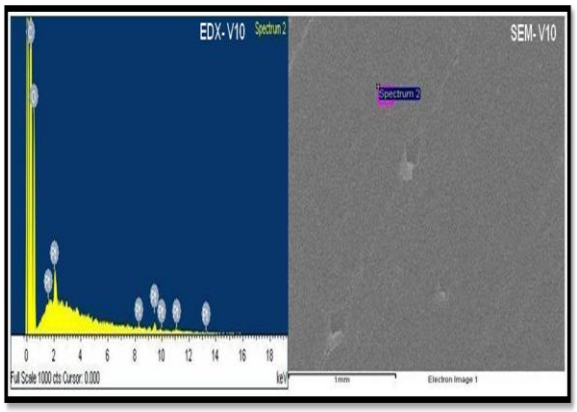

Fig: 14 SEM and EDX Scan of Virgin Plastic Sample (VI0)

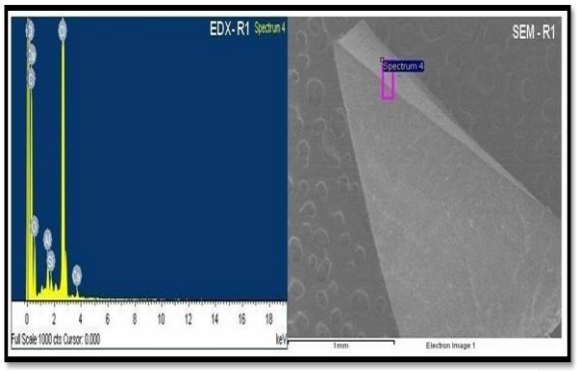

Fig: 15 SEM and EDX Scan of Virgin Plastic Sample (VI1)

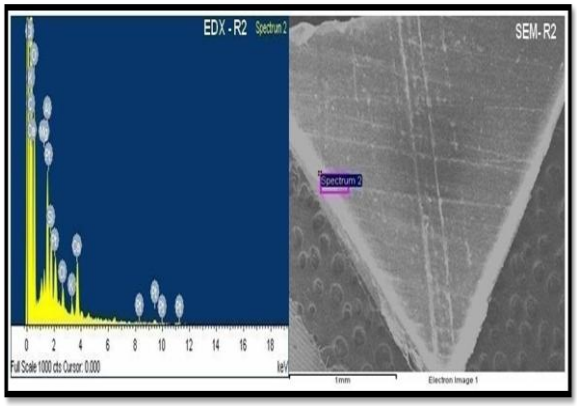

Fig: 16 SEM and EDX Scan of Virgin Plastic Sample (VI2)

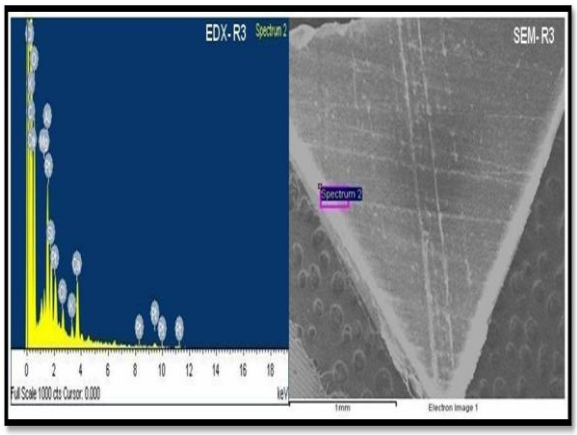

Fig: 17 SEM and EDX Scan of Virgin Plastic Sample (VI3)

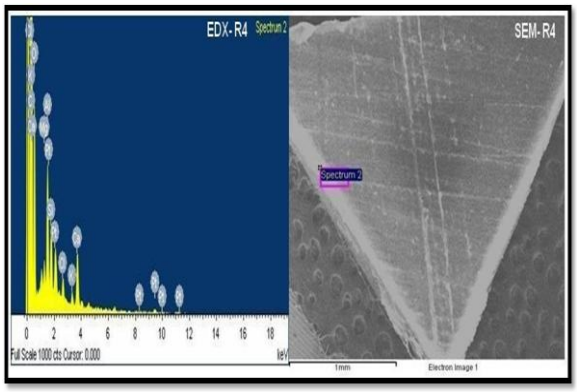

Fig: 18 SEM and EDX Scan of Virgin Plastic Sample (VI4)

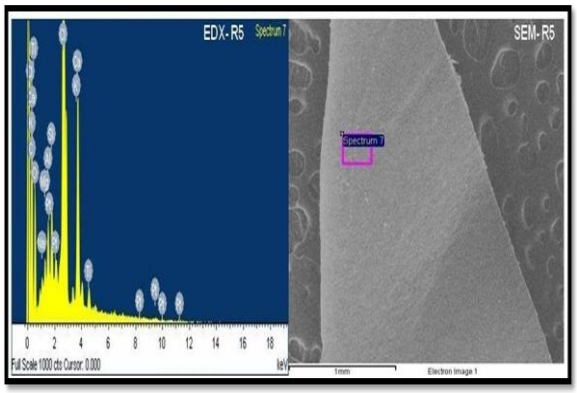

Fig: 19 SEM and EDX Scan of Virgin Plastic Sample (VI5)

CONCLUSION

The study parameters include physical state of the samples reveals the estimation of heavy metal content (cadmium, chromium, iron, arsenic, lead etc.) which are harmful if they leach out from packaging of foodstuff and drinking substances. Estimation by SEM/EDX shows complex chemical nature consisting of (benzene, alcohol, ether, amines, alkanes etc. Based on our study, we can conclude that the recycled plastics products are not recommended for use in product intend to come in contact with foodstuff. Sometimes incident contaminants may come from previous uses including possible misuse. Plastic container designed for food may be misused by the consumer who may use them to store chemical, and for other purpose, Guidelines for recycling plastics product have been framed by National regulatory agencies and being updated periodically but great efforts are needed for appropriate implementation at all levels.

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