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ANALYSIS OF THE IMPACT OF THE MINISTRY OF ENVIRONMENT BAN ON THE IMPORTATION OF RECYCLED PLASTIC RESIN

FINAL REPORT

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FINAL REPORT

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CONTENTS

INTRODUCTION.....	1
BACKGROUND	2
RESIN DEMAND IN JORDAN	3
CURRENT ECONOMIC IMPACT OF PLASTIC MANUFACTURING IN JORDAN	3
ECONOMIC IMPACT OF THE BAN ON IMPORT OF RECYCLED RESIN	4
RATIONALE FOR THE BAN	6
RISKS ASSOCIATED WITH CONTINUING THE BAN	8
CONCLUSION AND RECOMMENDATIONS.....	10
CONCLUSIONS	10
RECOMMENDATIONS	11
APPENDIX I.....	12
APPENDIX II.....	18
APPENDIX III.....	23

INTRODUCTION

The plastic recycling and manufacturing industry in Jordan is an important component of the manufacturing sector in Jordan, providing environmental benefits, as well as job creation through the manufacture of plastic products for use, both within Jordan as well as for export.

During a previous short-term assignment to SABEQ, the author worked with the plastic recycling industry to improve management practices to help insure that this sector would continue to grow as an important component of Jordan's private recycling and manufacturing sector. At the time of that assignment, interviews with plastic manufacturers who relied on recycled resin expressed significant concerns over a ban on the import of recycled resin from outside of Jordan.

Subsequent to that assignment, the Ministry of Environment proposed a new ban on the use of retail plastic bags in Jordan. SABEQ requested that the author return to Jordan to assist with a determination of the impact that such a ban would have on the plastic industry in Jordan. In conjunction with the analysis of the impact of a proposed ban on the use of retail plastic bags the author was asked to conduct additional research on the continued impact of the on-going ban on the importation of recycled plastic resin on the plastic manufacturing sector.

This draft report addresses this second objective . an analysis of the continuing impact of the ban on the importation of recycled plastic resin on the plastic manufacturing sector. A separate report will be submitted on the proposed ban on the use of retail plastic bags.

BACKGROUND

The plastic manufacturing sector in Jordan is a dynamic industry producing plastic products for sale in Jordan as well as for export. The Jordanian plastic industry ranges from large firms with multiple plants in the region: such as Adritec, producing state-of-the art drip irrigation piping; Agricultural Plastic Industrial Company producing high quality agricultural mulch and greenhouse films, and pioneering recycling of dirty mulch films; to firms such as Nizam Al-Baradi & Partners Co., manufacturing retail plastic bags for sale in Jordan as well as for export as far away as Dayton, Ohio, USA.

There are also many smaller, family owned plastic manufacturers producing a full range of plastic products for sale in Jordan. These include Awni Abu Sa'ad Plastic Factory and Orient Plastic Company, both of whom have been in business for more than thirty years, and involving multiple generations of the family, pioneering sophisticated plastic production technologies to produce a range of plastic packages and products.

One thing that all of the plastic manufacturers in Jordan have in common is the need to import virgin plastic resins from surrounding countries because Jordan does not have oil or natural gas reserves, even though it is surrounded by countries with some of the largest reserves in the world. Consequently, the Jordanian plastic manufacturers must rely on the competence of its work force, and their technological expertise to compete against companies in surrounding countries with a competitive advantage in terms of raw material input.

Over the past twenty years Jordan has attempted to grow the economy by exporting manufactured goods. Relatively high tariff and non-tariff barriers for products produced by Jordan manufacturers protected Jordanian manufacturers from lower cost imports, while Jordan ensured these same manufacturers access to cheaper imported capital goods, raw materials, and intermediate goods.¹

These tariff and non-tariff import barriers on finished goods made it easier for Jordanian plastics companies to compete for the Jordanian market as well as increase exports. However, more recently, as Jordan has moved to reduce trade barriers, it is now easier for companies in Saudi Arabia, especially, to import manufactured plastic products to Jordan and compete directly with Jordanian manufacturers because of the lower resin cost.² This is an especially critical problem for plastic manufacturers where material input (resin) costs often represent 70 percent of total production costs.

For this reason, as detailed below, the ban on the import of recycled resins to Jordan has serious negative consequences for plastic manufacturers in Jordan. This paper presents the results of the author's research on this issue, both in Jordan (May 17 - 29, 2009), as well as in the United States. During the time spent in Jordan the author:

- Conducted site visits to eight plastic manufacturing facilities;
- Met with the Managing Director of a plastics trading company;
- Met with the Ministers of Environment and Labor and Industry;
- Held two meetings with the Royal Scientific Society; and,
- Met with representatives of the Jordan Upgrading and Modernization Program.

¹ Excerpted from the Federal Research Division, Library of Congress, Country Studies, December 1989

² In addition, plastic manufacturers in Saudi Arabia do not have to pay customs on the import of goods to Jordan.

Upon returning to the United States, the author interviewed the Director of the Association of Post-Consumer Plastic Recyclers, as well as the Director Environment & Water Resources Europe for Coca-Cola GmbH, and conducted extensive research on Basel Convention issues, and activities in other countries concerning the importation of recycled resins. This report presents the author's findings, conclusions and recommendations.

RESIN DEMAND IN JORDAN

The author has not been able to find accurate data on total resin use in Jordan. However, research by SABEQ, confirmed by the author during discussions with plastic manufacturers and plastic resin trading companies, indicates that Jordan imports roughly 120,000 tonnes of virgin plastic resin per year, primarily from Saudi Arabia, but with significant quantities from as far away as South Korea. In addition, Jordan plastic manufacturers also purchase significant quantities of recycled plastic resin from Jordanian plastic recyclers.

As reported in the author's September 2008 report, there are no data on how much plastic is recycled in Jordan. However, a rough estimate can be made as to the demand for recycled resin from Jordanian plastic manufacturers (note that Jordanian plastic recyclers/reclaimers can sell recycled resin in Jordan and export recycled resin as well).

Pipe manufacturers, especially, as well as furniture manufacturers, can use as much as 50 to 70 percent recycled resin in their products. Film manufacturers can typically use less recycled resin, averaging an estimated 15 . 30 percent for retail bags and 30 . 50 percent for garbage bags.

However, food and pharmaceutical packaging producers, as well as many retail bag manufacturers use no recycled resin. In fact, the majority of plastic bag and packaging manufacturers that the author visited in Jordan did not use recycled resin, or only used their own regrind.

Given the uncertainty about the demand and supply of recycled resin in Jordan, a rough estimate is that total *current* demand for recycled resin in Jordan ranges from 15 to 30 percent of virgin resin use (or 18,000 . 36,000 tonnes per year). However, *potential demand*, assuming access to low cost, high quality recycled resin, could be as high as 60,000 tonnes per year.

CURRENT ECONOMIC IMPACT OF PLASTIC MANUFACTURING IN JORDAN

According to the Jordan Chamber of Industry, there are 330 plastic manufacturers in Jordan.³ Based on per employee resin consumption data provided to the author during interviews with plastic manufacturers, these plastic manufacturers employ between 3,000 and 4,000 people in the production and sale of plastic products. Assuming an average wage of 350 JD per month, plastic manufacturing generates roughly 13.5 to 16.5 million JD in annual direct wages per year and another 3.4 to 4.1 million JD in social benefits.

³ Eng. Anas A. Khasawneh, Officer, Industrial Affairs Department, Jordan Chamber of Industry, based on 2008 registrations.

Data are not available on the indirect and induced jobs generated from direct employment in the plastic manufacturing sector. Based on recent input/output models of the impact of plastic manufacturing in the northeastern United States, which the author helped develop, multipliers might range from 0.75 to 1.1. This would mean that another 2,500 to 4,400 indirect and induced jobs rely on the direct employment in plastic manufacturing, resulting in a total employment impact ranging from 5,500 to 8,400 jobs associated with the production of plastic products in Jordan.

ECONOMIC IMPACT OF THE BAN ON IMPORT OF RECYCLED RESIN

At current prices for PE resin (the largest single resin used/imported in Jordan) of roughly 915 JD per tonne, plastic manufacturers purchase roughly 110 million JD of virgin resin per year. Assuming that Jordanian plastic manufacturers use an additional 18,000 to 36,000 tonnes of recycled resin, at 690 JD, these same manufacturers purchase between 12.5 million and 24.8 million JD of recycled resin from Jordanian plastic recyclers.⁴

The ban on the import of recycled resin in essence acts in the same way as a tariff on the import of recycled resin does, in that Jordanian plastic recyclers/reclaimers do not have to compete on a price or quality basis with imported recycled resin suppliers. This allows plastic reclaimers in Jordan to charge a premium price for recycled resin and/or to sell lower quality recycled plastic resin than they would if they had to compete.

According to one of the largest plastic pipe manufacturers, at the time the ban on the import of recycled plastic resin was implemented, Jordanian plastic reclaimers were selling recycled resin for about one-half of the cost of virgin resin. This is consistent with the current spread between virgin and recycled resin prices for PE in the United States.⁵

In May 2009, it was reported to the author that the difference between imported virgin resin and recycled resin purchased from Jordanian reclaimers is currently roughly 25 percent.⁶

This means that plastic reclaimers in Jordan are currently able to price their recycled resin 25 percent points above market prices. While this is undoubtedly good for plastic recyclers/reclaimers in Jordan, the subsidy is in essence paid by plastic manufacturers in Jordan, placing them at a competitive disadvantage for export, and when competing in Jordan with imported plastic products. The subsidy is also paid by Jordanian consumers who purchase products made from recycled plastic.

An estimate of the subsidy can be made based on current demand for recycled plastic resin. Assuming current demand for recycled resin is 15 percent of virgin use, or 18,000 tonnes per year, Jordanian plastic manufacturers are currently paying roughly 4.1 million JD more for recycled resin than they should be. If the demand for recycled resin is 30 percent of the

⁴ Data are not readily available on the consumption of the major grades of plastic in Jordan. It is likely that PE is the single largest resin type, representing at least 60 percent of total plastic resin consumption.

⁵ Plastic News, June 22, 2009, comparison of virgin, extrusion grade LDPE film and Post Consumer recycled resin LDPE film pellets.

⁶ Meeting with Mr. Tarek H. Zu'bi, Chief Executive Officer, Adritec Group International, May 27, 2009.

demand for virgin resin, then Jordanian plastic manufacturers are paying 8.3 million JD more for recycled resin than they should be.

Part of this subsidy is absorbed by the manufacturers, making them less competitive against imported plastic products. And part of the subsidy is passed on to Jordanian consumers in the form of higher prices for plastic products. The impact of this ban/subsidy is two fold.

First, the higher price for recycled resin means that Jordanian plastic manufacturers produce less plastic product than they would if they had lower costs. It is not unreasonable to assume that the ban on the import of recycled resin, and the resulting higher price for material inputs, has reduced plastic manufacturing output in Jordan by 10 to 20 percent. If that is the case, then the ban is costing Jordan roughly 1,000 (rounded) direct and indirect jobs based on the ratio of plastic resin consumption to total employment in plastic manufacturing in Jordan.

Second, the ban on imported recycled resin forces some plastic manufacturers to use much less recycled resin than they would if they could purchase sufficient quantity and quality of recycled resin. For example, Adritec has developed a process for co-extruding plastic irrigation pipe that can use up to 80 percent recycled resin. However, because of the lack of sufficient high quality recycled resin from Jordanian plastic reclaimers, Adritec reports that they use no more than 30 percent recycled resin. Assuming that resin represents 70 percent of total costs to Adritec, the lack of available high quality recycled resin increases Adritec's cost by roughly 30 to 35 percent. This makes it extremely difficult to compete with pipe manufacturers from surrounding countries, both for export, and more recently for sale in Jordan.

RATIONALE FOR THE BAN

The Ministry of Environment (MOE) maintains that the reason for the ban is that imported recycled plastic resin could contain hazardous chemicals that could leach into food if used in retail plastic bags, or be a danger to children if used in toys or furniture. The MOE also maintains that the Basel Convention allows for the ban on the import of recycled resin because of Jordan's inability to adequately test for hazardous constituents in imported resin.

It is the author's professional opinion that both of the MOE's rationales for the ban are incorrect, for the following reasons.

Ban on Importation of Recycled Plastic Resin Does Not Protect Consumers from Potentially Hazardous Materials

There are two reasons why the ban on the import of recycled plastic resins by Jordanian plastic manufacturers does not protect Jordanian consumers from the threat of contamination by recycled resin.

First, plastic product manufacturers from outside of Jordan are not restricted from importing and selling products in Jordan. As governments around the world now know, there are risks associated with the import of Chinese products (see for example the article entitled *"China-made children's products unsafe – state media"* published in the Jordanian Times on May 29-30, 2009). The ban on the import of recycled plastic resin does nothing to reduce this risk.

Second, there is no restriction on Jordanian plastic recyclers grinding Chinese made products and/or agricultural plastics (that might be contaminated with pesticides and herbicides) to sell to Jordanian plastic manufacturers. Thus, for example, an imported Chinese plastic chair containing heavy metals could be recycled in Jordan, with the recycled plastic sold to a Jordanian plastic manufacture for use in a new plastic toy, without the knowledge of the Jordanian plastic toy manufacturer.

The Basel Convention Restricts Jordan from Banning Recycled Plastic Resin

Annex IIIV and Annex IX of the Basel Convention *Clarification and Characterizations of Wastes* lists *"wastes likely to be hazardous under the convention"* (Annex IIIV) and *"wastes not likely to be hazardous under the convention"* (Annex IX). Recycled plastic resins are listed in Annex IX, not in Annex IIIV. Annex IX specifically states: ***"Wastes placed in Annex IX will not be wastes covered by Article 1, paragraph 1(a) of the Basel Convention unless they contain Annex I material to an extent causing them to exhibit an Annex III characteristic."***

Jordan is a party to the Basel Convention.⁷ Parties to the Basel Convention can not ban the importation of green list wastes (Annex IX materials are green list materials as interpreted

⁷ Jordan signed the Basel Convention Treaty on June 22, 1989 and ratified it on December 6, 2004. See http://www.ban.org/country_status/country_status_chart.html

by the OECD which is responsible for enforcing the Basel Convention) unless they can prove that hazardous wastes (banned wastes) are present. Jordan does not have any proof that green list recycled resins imported to Jordan would be more likely to contain hazardous wastes than recycled resins produced in Jordan.

The American Society of Testing and Materials, International has published a *Standard Guide for Techniques to Separate and Identify Contaminants in Recycled Plastics*. A copy of this Standard is included Appendix 1 to this document.

The Royal Scientific Society (RSS) of Jordan is the logical institution in Jordan to test resins and plastic products for hazardous contaminants using the ASTM International Standard. However, the RSS does not currently have the capacity to conduct these tests.⁸ It is the author's opinion, after meeting with the RSS, that it will take a minimum of two years for the RSS to acquire the necessary testing equipment and train existing personnel to properly use the equipment.

Appendix 2 to this report presents the RSS list of equipment, and the estimated cost of this equipment, that the RSS believes would be necessary to begin such a testing protocol.

Once the RSS obtains the necessary equipment and trains RSS technicians in the operation of the equipment, a statistically valid testing protocol would have to be developed. This will require the development and implementation of a random sampling program to test recycled resin from a representative sample of Jordanian plastic reclaimers, and then obtain and sample recycled resins from suppliers outside of Jordan. This means that realistically it will be at least three years before the RSS would be capable of issuing an opinion as to the potential for hazardous contamination of recycled resins, both from Jordan and from imported resins.

However, even if the RSS were to determine that there were potentially hazardous chemicals in the recycled resin (either from Jordan or from imported recycled resins), it would still be necessary to determine if these chemicals were still present in potentially toxic amounts once they were used to manufacture new plastic products. This would require a statistically valid sampling protocol for testing of new plastic products manufactured from recycled resins, followed by a health risk assessment of the potential health risks associated with whatever levels of contaminants were found (if any).

In summary, it is the author's professional opinion that Jordan should move forward with the funding of the RSS request so that the requisite technical capacity becomes available in the future. It will be of significant benefit to Jordan, and to the plastic recycling and manufacturing sectors. However, waiting a minimum of two years, and more realistically three to four years to acquire the equipment and necessary training and then carry out a statistically valid sampling protocol risks the loss of significant plastic manufacturing capacity in Jordan. More importantly, waiting to develop this testing and analytical capacity, does not achieve the MOE objective given the import of plastic products that may contain hazardous chemicals in the interim.

No Other Countries Have a Blanket Ban on the Import of Recycled Resins

⁸ Meeting with Rafat Ahmad, PhD, Director, Industrial Chemistry Centre, May, 2009

An extensive internet search, together with discussions with other experts in plastic recycling has not identified any other countries that currently ban the import of recycled plastic resins. Two countries in Europe, Italy and Spain, have partial bans on the use of imported recycled resin for *food contact packaging only*.⁹ The Director of the Association of Post-Consumer Plastic Recycling (APR) in the United States confirmed that no such ban exists in the United States, and that he is not aware of any restrictions on the export of recycled plastic resins from United States plastics reclaimers.¹⁰

RISKS ASSOCIATED WITH CONTINUING THE BAN

Plant Closures

The greatest risk to Jordan is the loss of large irrigation pipe and agricultural mulch film manufacturers over the next several years if the ban remains in place. These firms are international firms, they require high quantities of recycled resin, and they can move their equipment at relatively low cost if purchased resin costs make them uncompetitive in the world market.

This is especially the case for Adritec, which is capable of co-extruding drip irrigation pipe with recycled resin sandwiched between two layers of virgin resin. Co-extrusion of recycled resin inside of virgin resin was the earliest way to obtain a Letter of No Objection from the United States Food and Drug Administration for food contact packaging in the United States. There should be no question about the safety of this process in the production of irrigation pipe in Jordan using recycled resin. At a minimum, the ban should be lifted immediately for co-extrusion for non-food applications.

However, it is the author's professional opinion that even without co-extrusion the risks of food contamination associated with the use of recycled resin in drip irrigation pipe is insignificant. As discussed in the previous report to SABEQ, and repeated here, drip irrigation pipe is typically made with a mix of virgin and recycled resin, diluting the potential contaminant. Assuming that one exists after washing, grinding and extruding to produce a pellet, then re-extruding to produce the plastic pipe. The pipe used in drip irrigation piping in Jordan is PE, which is relatively inert. That is why PE is used for landfill liners because it does not react to hazardous chemicals. This significantly reduces the potential for migration of a contaminant in the PE pipe. However, if migration of the contaminant occurs, it must be carried by the water to the soil, where it must be taken up by the root and transported to the edible portion of the vegetable (except for root crops where one less link in the transport pathway is necessary). At each step of this exposure pathway the risk is reduced, to the point where it is highly unlikely that a risk assessment would find an issue of concern. In fact, the real risk is much more likely to be the direct application of pesticides and herbicides to fruits and vegetables as part of the growing cycle, then the potential for migration from drip irrigation piping.

Reduced Jordanian Employment and Wages

⁹ Meeting with Dr. Klaus Peter Stadler, Director Environment & Water Resources Europe, and Director Commercialization & Stewardship Germany, Coca-Cola GmbH, Berlin Germany, July 8, 2009.

¹⁰ Telephone conversation with Steve Alexander, Director, APR, Washington, DC, June, 2009.

Even if Jordanian plastic manufacturers do not move their manufacturing facilities to other countries, the number of jobs for Jordanians is significantly reduced by the inability of Jordanian plastic manufacturers to obtain sufficient quantity and quality of recycled plastic resin. As discussed at the beginning of this report it is likely that at least 1000 plastic manufacturing jobs are lost in Jordan each year that the ban remains in place. This is equivalent to 5 million JD in wages and benefits annually.

The Ban May Increase the Risk of Contamination

There is a real risk that the ban on the import of recycled resins *increases* the risk of contamination of recycled resins produced in Jordan as plastic reclaimers search for new sources of plastic (including agricultural plastics and discarded plastic items manufactured in China) that may contain hazardous constituents.

The Ban Reduces Investment in New Manufacturing Capacity in Jordan

The inability to import recycled resins, together with the artificially high price for recycled resins in Jordan due to the ban reduces potential domestic and foreign investment in new plastic manufacturing capacity in Jordan. This further depresses employment as well as wages and tax revenues. It also plays a role in existing Jordanian company decisions with respect to where to locate another plant. This is especially critical given reported lower costs in Saudi Arabia.

CONCLUSION AND RECOMMENDATIONS

CONCLUSIONS

- There are 330 Jordanian plastic manufacturers in Jordan.
- These Jordanian plastic manufacturers employ an estimated 3,000 to 4,000 workers, with an estimated additional 2,200 to 4,400 additional indirect and induced jobs dependent on the plastic manufacturers.
- Total wages and social benefits realized as a result of the Jordanian plastic manufacturers are estimated to be between 17.9 and 20.6 million JD per year.
- The ban increases raw material costs to Jordanian plastic manufacturers by roughly 25 percent, resulting in an additional expenditure of between 4.1 and 8.3 million JD per year.
- The additional cost to purchase recycled resin results in an estimated loss of 1000 jobs, or 5.25 million JD in lost wages and social benefits.
- The ban does not protect Jordanian citizens because products made from recycled resin can still be imported into Jordan, and because the ban increases the use of more marginal recycled resins from within Jordan.
- The ban is in potential violation of the Basel Convention, which Jordan is a party to, because it bans green list materials (recycled plastic resin) without proof of contamination.
- The Consultant is not aware of any other countries in the world that ban the import of recycled plastic resin for non-food packaging applications.
- Jordan does not have the capacity to test for contamination of resins, either imported or domestic to prove that recycled resin from outside of Jordan is inherently more likely to be contaminated than recycled resin from Jordan.
- It will take a minimum of two to four years for the RSS of Jordan to acquire the necessary equipment, train staff, establish a statistically valid sampling protocol, and compile a large enough database to assure the integrity of all recycled plastic resins.
- In the interim, unless the ban is lifted Jordan risks the loss of existing plastic manufacturing capacity to neighboring countries, as well as the loss of an estimated 1000 plastic manufacturing jobs each year associated with reduced production of plastic products in Jordan as a response to artificially high recycled plastic resin prices.

RECOMMENDATIONS

- Jordan should provide RSS with the investment to acquire the necessary testing equipment and train competent staff to operate the equipment.
- Jordan should not wait for the RSS to acquire the necessary equipment and training, and to create a statistically valid sampling protocol, because it will take an estimated two to four years, and the ban will not protect Jordanian citizens in the interim
- The ban on the import of recycled plastic resin should be rescinded as soon as practicable because the ban does not protect Jordanian citizens from the potential for contamination by recycled plastic resin produced in Jordan, and from plastic products produced outside of Jordan and imported to Jordan. Failure to rescind the ban risks the loss of significant plastic manufacturing capacity in Jordan.
- Jordan should step up efforts to assure that food grade packaging is not produced with recycled resin. All of the food grade-packaging producers that the author visited reported that they do not currently use recycled plastic resin, and have no plans to do so.
- Jordan should consider the prohibition of the use of black plastic retail bags as one way to ensure that retail bags containing recycled resin are not used for food.

APPENDIX I



Designation: D 3077 - 14 (Reapproved 2015)

Standard Guide for Techniques to Separate and Identify Contaminants in Recycled Plastics¹

This standard is issued under the designation D 3077; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last approval of a previous edition. Comments on existing standards or requests for new standards should be addressed to ASTM.

1. Scope

1.1 This guide is intended to provide information on available methods for the separation and identification of contaminants such as inorganic, thermoplastic polymers, metals, adhesives, glass, paper, wood, chemicals, and organic-product residues in recycled plastic flakes or pellets. Although no specific methods for identification or characterization of these products are included, these products are not included from this guide. The methods presented apply to post-consumer plastics.

1.2 The specific procedures existing in ASTM test methods, this guide only lists the appropriate references. Where no current ASTM standard exists, however, this guide gives procedures for the separation or identification, at least, of specific contaminants. Appendix X1 lists the tests and the specific contaminants addressed by each procedure.

1.3 This guide does not include procedures to quantify the contaminants unless this information is available in referenced ASTM standards.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Note 1—Although this guide references ISO standards, there is no reader or approved ISO standard covering this topic.

2. Referenced Documents

2.1 ASTM Standards:

- D 155 Test Methods for Determination of Relative Viscosity, Melting Point, and Moisture Content of Polymers (PVC)²
- D 192 Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement³
- D 483 Terminology Relating to Plastics⁴
- D 602 Test Method for Heat and Cumulative Densitometric of Thermoplastic Plastics⁵

¹The guide is under the jurisdiction of ASTM Committee D19 on Plastics and is the direct responsibility of Subcommittee D19.04 on Recycled Plastics.

²Current edition approved January 15, 2015. Published March 2015. Originally approved in 1995. Last previous edition approved in 2004 as D 155 - 04.

³Approved as D 192 standard, May 2015.

D 1495 Specification for Rongex Niro⁶

D 1229 Test Method for First Rates of Thermoplastic by Extrusion Plastomers⁷

D 1487 Specification for Poly(methacrylates) (PMMA) Molding and Extrusion Materials⁸

D 1585 Test Method for Density of Plastics by the Density Gradient Technique⁹

D 1899 Practice for Sampling of Plastics¹⁰

D 1424 Test Method for Inflammation Index of Plastics¹¹

D 5414 Test Method for Transition Temperature of Polymers by Thermal Analysis¹²

D 4019 Test Method for Moisture in Plastics by Coulometric Regeneration of Phosphorus Pentoxide¹³

D 5933 Guide for the Development of Standards Relating to the Proper Use of Recycled Plastics¹⁴

D 3221 Test Method for the Measurement of Residue (Extractable Content) of Polypropylene¹⁵

E 108 Practice for General Techniques of Ultraviolet-Visible Quantitative Analysis¹⁶

E 305 Practice for Gas Chromatography Terms and Definitions¹⁷

E 382 Practice for Liquid Chromatography Terms and Definitions¹⁸

E 766 Test Method for Melting and Crystallization Temperatures by Thermal Analysis¹⁹

E 1352 Practice for General Techniques for Qualitative Infrared Analysis²⁰

2.2 ISO Standards:²¹

ISO 14755:1-1985 Plastics—Determination of Ash, Part 1: General Methods

ISO 1183:1987 Methods for Determining the Density and Relative Density of Thermoplastic Plastics

3. Terminology

3.1 This terminology used in this guide is in accordance with Terminology D 483 and Guide E 593.

²²Approved as D 3077 standard, May 2015.

²³Approved as D 3077 standard, May 2015.

²⁴Approved as D 3077 standard, May 2015.

²⁵Approved as D 3077 standard, May 2015.

²⁶Approved as D 3077 standard, May 2015.

²⁷Adapted from American National Standards Institute (ANSI), Z39-48 and Z39-49, New York, 1968, 1971, 1976.

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1.3 Definition of Terms (applies to This Standard)

1.3.1 density—contaminants in test items materials (for example, inclusions or blemishes) generally used to extend test plastic materials.

1.3.2 glee—adhesive used for labels or joining test parts (for example, ethylene-vinyl acetate).

1.3.3 heavy metals—metals heavier than sodium on the periodic table (for example, lead, arsenic, cadmium, chromium, or copper).

1.3.4 heavy plastic—solid polymers such as polystyrene, polycarbonate, acrylonitrile, and polyvinyl chloride and filler materials with densities greater than 1.00 g/cm³.

1.3.5 light plastic—polymers such as polyethylene and polypropylene with densities less than 1.00 g/cm³.

1.3.6 original product residues—residues from any original product contents of a plastic package (for example, milk, juice, or detergent).

1.3.7 particles—pieces of waste, glass, wood, paper, or other differently shaped material equal to or larger than 0.1 mm².

1.3.8 specific—any material equal to or less than 0.1 mm².

2. Summary of Guide

2.1 This guide provides details of several procedures for inspection and density determinations including, but not limited to, residues, original product residues, incompatible plastics, wood, paper, glass, adhesives, and waste in recycled plastic films or pellets. This guide has revised ASTM and ISO methods that are too old to characterize solid and some liquid contaminants. In addition, this guide presents details of some industry procedures for identification of contaminants. Appendix A provides information on quantitative aspects of some of these industry standards that can also be used to measure the concentration of various contaminants.

3. Significance and Use

3.1 Recycled plastic materials may contain incompatible plastics or other undesirable contaminants that could affect the processing or quality, or both, of the plastic prepared for reuse. Techniques to separate and identify incompatible plastics, residues, chemicals, or original product residues, and solid contaminants such as wood, paper, glass, and wax are essential to the processing of recycled plastic materials.

3.2 This guide has revised ASTM and ISO methods plus commonly practiced industrial techniques for identification and classification of contaminants in recycled plastic films or pellets.

4. Sampling

4.1 Unless otherwise stated, materials should be sampled in accordance with the procedures described in Practice D 199. Adequate statistical sampling should be considered as an acceptable alternative.

5. Existing ASTM and ISO Procedures

5.1. Materials

5.1.1 A colorimetric method (Test Method D 4019), the standard test method for wax (Test Method D 199), and Fluor test (Test Method D 705), or a gravimetric procedure

(see 1.3.1) of Specification D 1473 can be used to measure the moisture content of recycled plastic materials.

5.2. Visual Inspection and Product Consistency

5.2.1. Color

5.2.1.1 Test Method D 1939 measures the yellowness index of clear acrylic plastics and the haze and the luminance transmittance procedure (Test Method D 1935) characterizes the color of transparent pigmented recycled plastic materials. These tests are not readily applied to pigmented plastic samples.

Note 1—Test Method D 1935 is currently being revised by ASTM Subcommittee D19.01 to address transparency and haze problems.

5.2.2 Test Flow for Product Consistency—Uniformity of color recycled plastic films or pellets can be determined by measuring the flow rate of the material using an extrusion procedure (Test Method D 1236).

5.3. Density or Specific Gravity—The displacement method for specific gravity or relative density (Test Method D 792) or the density-gradient procedure for density (Test Method D 1555) are useful techniques to determine contamination of recycled plastic films or pellet samples with one or more other polymers.

Note 2—Test Method D 1555 can identify small air pockets, or it can not be applied to samples of nonhomogeneous recycled plastic materials.

5.4. Inorganic Contaminants

5.4.1 An infrared, such as DSC-1400, or the methyl orange technique currently being evaluated within ASTM Subcommittee D20.75 (project designation X70-X702) can be used to measure the inorganic filler content of recycled plastic films or pellets.

Note 3—Some reliable results may be obtained for one substance in 7.4.1. ASTM Subcommittee D20.75 is currently developing other useful project X70-X702 for which, including heavy metals, that will include complementary techniques to measure the loss of volatile solids prior to analysis by X-ray fluorescence or spectroscopic techniques.

5.4.2 Various liquid contaminants can be measured with a magnet and chemical contaminants can separated from plastic materials using density procedures in accordance with 6.3.

5.5. Thermal Analysis

5.5.1 Since most polymers exhibit unique temperatures for melting or other phase transitions, measurement of these transition temperatures (Test Method D 3433) or the melting and crystallization temperatures (Test Method D 794) of a sample may provide useful information regarding the identity of polymeric components present in a recycled plastic material.

5.5.2 Both Test Methods D 3433 and D 794 involve thermal gravimetric analysis (TGA) or differential scanning calorimetry (DSC). These techniques require small samples (5 to 10 mg), so they may not be practical for use in characterization of generally nonhomogeneous recycled plastic materials.

5.6. Infrared Analysis—Quantitative infrared analysis using the technique of Practice E 1252 can be used to identify polymeric, chemical, and, in some cases, inorganic components of recycled plastic materials. Sample size considerations indicated in 7.3.2 may also apply to preparation of samples for infrared analysis.



7.7 Chromatographic analysis—The principles of gas chromatography, described in Practice 3.303, and liquid chromatography, described in Practice 3.302, are useful for separation and identification of chemical constituents or residues from original-use containers or plastic packaging.

8. Additional Instrumental Procedures

8.1 Specimen Preparation

8.1.1 Using standard equipment including equipment, proper homogenized sample plaques.

8.1.2 Plaques or slices from plaques prepared in 8.1.1, can be used for differential scanning calorimetry (DSC), infrared analysis, and other test procedures requiring small, homogenized specimens.

8.2 Fluids Separation Procedures

8.2.1 Impaction Table for Large, Flexible Containers

8.2.1.1 Using a laboratory spreader, spread 400 ± 20 g of recycled plastic flakes or pellets in a clean, white impaction table.

8.2.1.2 Without the benefit of magnification, describe the types of material constituents "particles" as defined in 3.2.7, then using 10× magnification, describe the "species" as defined in 3.2.8.

8.2.1.3 Thermal techniques (see 7.7) and infrared analysis (see 7.6) can be used to identify some of the isolated constituents.

Note 1—To obtain a qualitative estimate of the constituents, these constituents can be removed and weighed, but there is no melting point, and low heat index in the isolated constituent container from the initial analysis.

8.2.2 Impaction of Molten Specimens or Plaques

8.2.2.1 Weigh 4 to 5 g of dry plastic flakes or in a polymer sheet or aluminum foil in a 15.2 by 15.2 by 0.075 cm mold. Cover with another sheet of polymer film or aluminum foil, then adjust the press temperature to at least 175°C above the melting temperature of the bulk of the test material.

8.2.2.2 Press a plaque from the recycled plastic sample. Remove the plaque from the press and cool.

8.2.2.3 Visually examine the test plaque within a closed¹ area using a fluorescent-light table. For comparison, repeat 8.1.1 and 8.1.2 with a portion of virgin resin representing the bulk of the test material. (For example, polyethylene terephthalate (PET) if you are concerned in containers or recycled PET).

Note 4—The presence of glass contamination is indicated by breaking of the plastic in the specimen that used as a mirror material during cooling of the plaque.

Note 5—For alternative procedure for identification, longitudinal fracture testing (specimens for 10 min at 175°C in an aluminum pan. The melt is rapidly quenched in ice water to produce representative and the resulting test or group is visually inspected the constituents and the results are compared with a control also as plaques prepared from virgin PET. In this case, melt specimens subjected to degraded paper, carbon, polymer, or other contaminants in the polyethylene terephthalate.

8.3 Separation of Resin or Density

8.3.1 Water-Density Separation

8.3.1.1 Put a clean plastic container with 1 L of clean water. Add sufficient sodium chloride to make a 2% (weight/volume) solution and mix thoroughly.

Note 6—Homogenizing the water quickly mixes the entire part of the container and the container. This quality for the test isolates properties of type II grade (single water or solvent is specified in 3.1.1).

Note 7—For plastic resin this material may cause the material to feel tacky or soft. The solution (for example, 100 ± 100% resin) causes the plastic resin plastic film.

8.3.1.2 Obtain a representative sample of recycled plastic flakes (see 8.1) and weigh 100 ± 10 g into a clean, dry plastic container.

Note 8—The sample should be free of particles retained by a previous test as described in 8.1.

8.3.1.3 Add the solution solution from 8.3.1.1 to the sample container and mix well with a spatula. Allow solids to settle for at least 5 min.

8.3.1.4 Stir the light plastic and any contaminants (for example, paper) from the top of the mass using a small kitchen spoon. Transfer these materials to a larger container and treat with water to remove residual materials.

8.3.1.5 Pour the remaining contents from the sample container (see 8.3.1.4) through another large screen and wash these heavier materials with water to remove residual surface film.

8.3.1.6 If desired, these collected heavy materials are dried and characterized by thermal (see 7.7) or infrared (see 7.6) techniques.

8.3.2 Propagated Water Density Separation

8.3.2.1 Add 1000 mL of 2-propanol and 1000 mL of water (distilled, deionized, or deionized) to a 9-L plastic bottle. Mix well to produce a solution containing 52 % (volume/volume) 2-propanol in water.

8.3.2.2 Pour 100 mL of the solution from 8.3.2.1 into a 100-mL graduated cylinder and measure the specific gravity of this solution with a hydrometer. The specific gravity should be between 0.954 and 0.957. If not, add small amounts of 2-propanol or water to the solution from 8.3.2.1 to bring the specific gravity into the desired range.

8.3.2.3 Weigh 100 ± 10 g dry light plastic (see 8.1) in less a 4-L plastic jug, then add the 70 % 2-propanol/water solution (see 8.3.2.1) to this container. The container with a rubber spout or not all films, then allow solids to settle.

8.3.2.4 Stir any plastic from the top of the solution with a small kitchen spoon. Transfer the separated material to a larger container and mix with water.

8.3.2.5 Pour the remaining contents from 8.3.2.3 through a large screen and collect the 2-propanol/water solution in a clean, dry bottle. Save this solution for reuse in other separations. Stir the plastic in the container with water to remove residual 2-propanol.

8.3.2.6 If desired, dry the plastic in the container, then characterize the material using thermal (see 7.7) or infrared (see 7.6) techniques.

¹ Enclosed.

² Includes both State of New York, Independent National Police, and other.

8.4. Instrumental Flow Chart

8.4.1. To estimate the relative level of contamination, pass the recycled plastic through a laboratory screen equipped with a filter screen.

8.4.2. The level of contamination is measured as a decrease of the rate of pressure increase resulting from increased deposits on the filter screen.

8.4.3. Contamination noticed on the screen can be characterized by chemical (see 7.3) or infrared (see 7.5) techniques.

8.5. Chemical Polymer Composition

8.5.1. Flame Test (Reference Test)

8.5.1.1 Heat the flame of a Bunsen burner, then pick up a sample of the test plastic with tweezers.

8.5.1.2 Place the hot end of a copper wire in the flame until it turns to a dull orange color, then quickly remove the wire from the flame and touch it to the sample.

8.5.1.3 Press the wire into the plastic sample and allow the sample to melt on to the wire.

8.5.1.4 Remove the wire from the sample, place the wire with the sample back into the flame, and hold the wire in the flame until the plastic sample burns off the wire.

8.5.1.5 The presence of a chlorinated polymer is indicated by a strong green flame during 8.5.1.4.

8.5.1.6 When all samples have been tested, turn off the gas to the burner and close the burner.

8.5.2. Test A Test

8.5.2.1 Prepare a Test A master batch by adding 1.00 g Styrene Dilluent Red B, 1.00 g Isopar N100, and 2.00 g Tensol Polysilox Blue BCN dye¹⁰ to 1 L water heated to 60 ± 2 °C. Stir until dye is completely dissolved, then remove the mixture from the heat, cool, and transfer to a suitable container.

8.5.2.2 Prepare a test solution by mixing 17 mL of Test A (see 8.5.2.1), 200 mL of water, 50 mL of 1 % Tensol solution,¹¹ and 2 mL 1 % (undiluted) acetic acid in a suitable container.

8.5.2.3 Place the test solution in a 500-mL beaker on a hot plate and add approximately 100 g of the recycled plastic.

8.5.2.4 Heat the mixture for 5 min, then remove the beaker from the hot plate.

8.5.2.5 Decant the liquid, clean the plastic thoroughly with water, and transfer the washed plastic to a clear plastic bag.

8.5.2.6 Visually determine the presence of colored plastic under fluorescent light. Poly(vinyl chloride) and poly(vinylidene chloride) are purple, while polymers appear as the expected, and polyamides appear yellow or orange.

8.6. Test B Test for Nylon and Polyamides

8.6.1 Add 1 mL NaCl, 2 drops of a sodium solution, 0.1 g of Test A, and 100 mL of water to a 500-mL beaker.¹²

8.6.2 Add approximately 100 g of recycled plastic to the beaker and place the beaker on a hot plate.

8.6.3 Heat the mixture for at least 2 min, then remove the beaker from the hot plate.

8.6.4 Pour the beaker contents into a strainer and rinse with cold water.

8.6.5 Visually examine the washed plastic under fluorescent light. Nylon/polyamides samples will turn green or blue-green, polyamides will turn yellow, and paper contamination will appear as red material.

8.7. Infrared Absorption (Reference)

8.7.1. Sample description

8.7.1.1 Weigh 100 g of recycled plastic into an 800-mL Erlenmeyer flask and add 100 mL of p-xylene.

8.7.1.2 Heat the flask with a cork stopper fitted with a thermometer. Adjust the thermometer so that the bulb touches the bottom of the flask.

8.7.1.3 Maintain a temperature of 60 ± 2 °C and heat the solvent until sample on a hot plate for 1 h. Stir the flask every 1 to 2 min to mix the contents.

8.7.1.4 After 1 h, cool the sample to room temperature.

8.7.1.5 Transfer a portion of the p-xylene content to a suitable cell and obtain an infrared spectrum of the content versus a p-xylene reference liquid in accordance with Practice E 125. Appearance of an absorption band at 6.7 µm indicates the presence of an aliphatic vinyl acetate (VAc) copolymer. Other bands in the infrared spectrum may be characterized in accordance with Practice E 125.

8.7.2. Reference Extraction

8.7.2.1 To adapt this method (E 527) to the determination of contaminants in recycled plastic materials, add 1 L of xylene to the waste bottle in accordance with Test Method E 527 and change the bottle assembly into a waste bottle maintained at 60.0 ± 0.2 °C.

8.7.2.2 Add 2.5 to 3 g of the plastic sample, replace the bottle head with a condenser, and extract the sample for 2 h.

Note: (E)—The procedure described for identifying can be modified for use with other polymers by using higher boiling solvents and increasing extraction temperature.

8.7.2.3 After extraction, filter the waste bottle contents through a filter medium (see 8.7.2.4).

8.7.2.4 Analyze an aliquot of the filtered extract using thermal techniques (see 7.3), infrared spectroscopy (see 7.5), or a suitable alternative technique such as gas chromatography to identify the extracted components.

8.8. Polyesters or p-Cyanamides

8.8.1 Weigh 50 g of the recycled plastic sample into an Erlenmeyer flask and shake 1 h with 100 mL of a solvent that is transparent at 214 nm (for example, dichloromethane or trichloroethylene) based on spectroscopic techniques of Practice E 109.

8.8.2 Dilute 2.5 mL of the extract to 50 mL with the same solvent.

8.8.3 Filter 5 mL of this solution through a 0.45-µm filter on a 0.45-µm filter.

8.8.4 Obtain the infrared spectrum of the filtered extract in accordance with Practice E 109. Compare the absorbance at 214 nm with the absorbance of a solvent blank. Significant absorbance at 214 nm indicates the presence of a polyester.

¹⁰Tensol Dilluent Red B is available from Unipol & Son, Inc., Ontario, NY, and 80 other sites on condition that Unipol pays royalties to the

¹¹Tensol liquid is available from Tensol Sales Corp., Norfolk, VA.

¹²See 8.6.1 for details about sodium solution. For testing of cyanamides, 10 (20) mL of a cyanamide solution can be used to heat the flask through a medium flow (1 liter/hr, 10 min/hr, 10 min/hr).

defined as either aromatic species (for example, polystyrene and isobutylene) or poly(ethylene terephthalate).

100

- R.1.2 The techniques used to arrive at the classification reported in R.1.1.

- (1) composite moldings, composites, thin-walled sections, reinforced plastic, crystal plastic, metal supports

Abstract

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TABLE 1. *Summary of the 1996-1997 and 1997-1998 field seasons. The number of fish collected and the number of fish that were sexed are given. The number of fish that were sexed is given in parentheses. The number of fish that were sexed is given in parentheses.*

TABLE 1. *Continued* **Characteristics of Participants Addressed to Specific Age Groups**[illegible]

As the manufacturer of a device requiring the safety of its users, you should consider all the risk factors in the design, construction, operation, and use of the device, and the distribution of the safety of the end-user, and the use of the device in a safe manner.

[illegible]

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APPENDIX II

A Proposal for Upgrading f Plastic Characterization Unit for Testing & Monitory of Plastic Materials & Products in Jordan

Mission and Objectives

The mission of the proposed **Plastics Characterization Unit** is to provide, through technical testing, research and monitory activities, the means ***to ensure that plastic product is safe and meets domestic and foreign regulatory requirements***. This will help to decrease the hazards of both virgin and recycled products. Moreover, by enforcing measures for the testing of plastic products, the ***consumers will be protected***, and consequently, the ***growth of Jordan's plastics industry will be promoted***.

Output

Once established at the Royal Scientific Society (RSS), the **Plastics Characterization Unit** will be an example of a leading entity that will be a natural evolution of RSS continuous development.

This unit will offer a comprehensive range of state-of-the-art mechanical, thermal, and chemical Analysis tech niques.

Introduction

There is a significant increasing need for the plastics industry to meet the challenge in reducing the amount of solid waste disposals by resorting to the use of recycled materials in the fabrication of products. However, **due to the permeable nature of plastics, the possibility that chemical contaminants resulting from post-consumer misuse** (automotive fuels and oils, solvents, pesticides, toxic organic salts involving heavy metals, antifreeze, household cleaners, etc.) **remain in the recycled plastics and migrate into food**, for example, which is one of the major concerns regarding the safety of recycled plastics used in food packaging applications, and other applications i.e. medical, textiles, etc.

Therefore, manufacturers of virgin/recycled plastic materials made for human-direct-use **must test the physical and chemical properties of virgin/recycled plastics in the same manner as virgin materials, to ensure that the plastic products are of suitable purity for their intended use and will meet all existing specifications for the virgin plastics, and meet the technical requirements for their functional purposes.**

RSS applies multiple techniques, such as spectroscopy, chromatography and microscopy to examine the components of plastic and polymer products.

The materials identification services to the plastics industry will include physical testing and chemical analysis as follows:

- Contaminant identification
- Additive analysis
- Quality issues (virgin or recycled polymer)
- Base polymer identification
- Average molecular weight and distribution

Overview of Testing & Research Components

RSS has three diversified laboratories dealing with chemical and mechanical testing. The Rubber and Plastics Laboratory, the Chromatography Laboratory (organic identification), the Spectroscopy Laboratory (inorganic identification), and Radiation laboratory. These laboratories, combined, have strong technical capabilities and an impressive aggregation of expertise. The staff of these laboratories is committed to achieving the Plastics Characterization Unit goals through working on the following research components:

1. Plastics Physical Characterization and Testing

The physical properties (mechanical and thermal behavior) of polymer are changing after they are processed into final products. Therefore, plastics characterization and testing are needed to distinguish between products that are produced from virgin or already recycled (post-consumer) plastics.

The Rubber and Plastics Laboratory at MDTC offers valuable consultancy and testing services for the identification, characterization and evaluation of polymeric materials and products. It also offers on-site supervision on locally produced plastic items for key projects in Jordan. The technical competence of the Plastic and Rubber Laboratory is recognized nationally and internationally. It is the first testing laboratory in Jordan to be granted national accreditation.

Our goal is to develop tests that are precise, reliable, and rapid enough to detect if the plastic product/ materials are made from virgin/or/recycled raw polymer prior to their admittance to the market.

2. Chemical Contamination & Residue

The possibility that chemical contaminants in plastic materials intended for recycling may remain in the recycled material and could migrate into the surrounding the material contacts is one of the major considerations for the safe use of recycled plastics for human-contact applications.

Serious consequences have been reported when plastic products contaminated with pesticides or, toxic organic salts involving heavy metals, such as lead, cadmium, or mercury; have been utilized by people. Effective detection of chemical residues in food can greatly

reduce the risks of causing health problems. Thus, both organic and inorganic analyses need to be enhanced at ICC to be able to cover the type of analyses required.

ICC is staffed with experienced technologists and scientists who are working with a variety of analytical instruments to determine chemical constituents in a range of sample matrices. **The Organic Chemistry Division** applies sophisticated technologies to the surveillance of chemical residues in different products using GC/MS units. RSS has an extensive track record of providing analytical and consultancy services to the "National Committee for Studying the Impact of Pesticides on the Environment". **The Pesticides Residue Laboratory** is equipped with Gas Chromatographs linked to Mass Spectrometers (GC-MS) for the routine analysis of pesticides (organochlorines). **The Inorganic Chemistry Division** performs determination of heavy metals, such as lead, mercury, cadmium, copper, iron, zinc, or major ions, such as sodium and calcium.

The major goal is to develop reliable, effective, accurate, user-friendly, and cost-effective residue detection methodology that requires minimal amounts of organic solvents to detect these residues in plastic products prior their admittance to the local market.

Requirements

The effectiveness of this unit is largely dependent on the available resources, the available equipment, technical capability and capacity, knowledge, skills and abilities of the staff, and access to technically up-to-date information and methods.

Upgrading and modernization of RSS's Plastic Characterization Unit will involve:

- **Upgrading Laboratory Equipments**

The required equipments are:

- 1) Thermogravimetric analysis (tga) or thermal gravimetric analysis (more specifications are provided in the appendix).
- 2) Differential scanning calorimetry (dsc) (more specifications are provided in the appendix).
- 3) Thermo-mechanical analysis (more specifications are provided in the appendix)
- 4) Cutter machine for sample preparation for testing machine
- 5) Twin-extruder system and injection molding (lab scale) for sample molding
- 6) Gc-ms headspace (upgrading)
- 7) UV-Spectrophotometer (upgrading)
- 8) SEM/EDXA (new machine)

- **Personnel Skills**

Although the educational background of current staff is generally high, the staff is not familiar with the state-of-the-art analytical equipment and analytical methods. Therefore, ***we believe specialized training is required to raise the performance of existing and new staff to a professional level.***

Budget

The total estimated budget to establish this unit at RSS is 200,000 JD (Two hundred thousands JD). In addition to the advanced instrument which should be available as well, which is SEM/ EDXA and its cost is 270,000 JD (Two hundred and seventy thousands JD).

The budget is distributed as follows:

	Machine	New/ or Upgrading	Cost [JD]
1	Differential Scanning Calorimetry DSC	New	30 000
2	Thermogravimetric Analysis TGA	New	15 000
3	Thermo-mechanical Analysis TMA/ DMTS	New	30 000
4	Cutter machine for sample preparation	New	5 000
5	Twin-extruder system and injection molding (lab scale)	New	25 000
6	Gel Permeation Chromatography GPC	New	30 000
7	GC-MS headspace	upgrading	15 000
8	UV-Spectrophotometer/ configuration for plastics	upgrading	15 000
9	Spare parts and consumables	--	25 000
10	Training	--	10 000

	Advanced Instrument	New/ or Upgrading	Cost [JD]
1	SEM/ EDXA (advanced instrument)	New	270 000

Expected Outcome and Benefits

1. Novel tools will be developed and evaluated as potential standard tools in support of health, environment, and safety policy making in Jordan.
2. The upgraded laboratory will be a sound technical arm for the government in terms of applying national and international plastics specifications, and providing expert opinion and consultations.
3. The upgraded laboratory will perform third-party verification tasks for quality control/assurance of plastics testing.
4. Jordan's policy makers and plastic sectors will negotiate existing and forthcoming plastic product safety issues based on strong and scientifically sound evidence.
5. Identification of emerging plastics hazards and contaminants.
6. No hazardous plastic waste and minimal chemical residues in plastic products reaching the consumer.
7. Plastics Characterization Central Unit will be accessible and beneficial to the scientific community.

Today's investments in plastics characterization research and monitoring will result in tomorrow's savings in health-care and industry costs. Knowledge generated in this area will push Jordan to compete on the international scale.

APPENDIX III

1) The Thermogravimetric Analysis (TGA) Technique

- TGA measures the amount of weight change of a material, either as a function of increasing temperature, or isothermally as a function of time, in an atmosphere of nitrogen, helium, air, other gas, or in vacuum.
- Inorganic materials, metals, polymers and plastics, ceramics, glasses, and composite materials can be analyzed.
- Temperature range from 25°C to 1000°C routinely. The maximum temperature is 1000°C.
- Sample weight 1 g including tare.
- Weight change sensitivity of 0.001 mg.
- Samples can be analyzed in the form of powder or small pieces so the interior sample temperature remains close to the measured gas temperature.

Applications of Thermogravimetry

- Determines temperature and weight change of decomposition reactions, which often allows quantitative composition analysis. May be used to determine water content.
- Allows analysis of reactions with air, oxygen, or other reactive gases (see illustration below).
- Can be used to measure evaporation rates, such as to measure the volatile emissions of liquid mixtures.
- Allows determination of Curie temperatures of magnetic transitions by measuring the temperature at which the force exerted by a nearby magnet disappears on heating or reappears on cooling.
- Helps to identify plastics and organic materials by measuring the temperature of bond scissions in inert atmospheres or of oxidation in air or oxygen.
- Used to measure the weight of fiberglass and inorganic fill materials in plastics, laminates, paints, primers, and composite materials by burning off the polymer resin. The fill material can then be identified by XPS and/or microscopy. The fill material may be carbon black, TiO_2 , CaCO_3 , MgCO_3 , Al_2O_3 , $\text{Al}(\text{OH})_3$, $\text{Mg}(\text{OH})_2$, talc, Kaolin clay, or silica, for instance.
- Can measure the fill materials added to some foods, such as silica gels and titanium dioxide.
- Can determine the purity of a mineral, inorganic compound, or organic material.
- Distinguishes different mineral compositions from broad mineral types, such as borax, boric acid, and silica gels.

ASTM Test Methods Using Thermogravimetric Analysis

- ASTM D2584 - Standard Test Method for Ignition Loss of Cured Reinforced Resins
- ASTM E1131 - Standard Test Method for Compositional Analysis by Thermogravimetry

2) The Differential Scanning Calorimetry (DSC) Technique

- DSC is used to measure melting temperature, heat of fusion, reaction energy and temperature, glass transition temperature, phase transition temperature and energy, and specific heat or heat capacity.
- DSC measures the amount of energy absorbed or released by a sample when it is heated or cooled, providing quantitative and qualitative data on endothermic (heat absorption) and exothermic (heat evolution) processes.
- Only non-corrosive samples can be analyzed in this very sensitive instrument. No organic or other materials containing F, Cl, Br, or I may be submitted for DSC analysis. The customer must either tell us what the material is or at least that it is non-corrosive and assume responsibility for possible replacement of a \$3000 DSC cell if a cell is destroyed as a result of the analysis of their sample. Or, you may have us perform such analysis as may be needed to determine what the material is and whether it can be analyzed in the DSC.
- Number of samples: 24 samples per tray.
- The sample is placed in a suitable pan and sits upon a constantan disc on a platform in the DSC cell with a chromel wafer immediately underneath. A chromel-alumel thermocouple under the constantan disc measures the sample temperature. An empty reference pan sits on a symmetric platform with its own underlying chromel wafer and chromel-alumel thermocouple. Heat flow is measured by comparing the difference in temperature across the sample and the reference chromel wafers.
- Temperature can range from -140°C to 600°C, though an inert atmosphere is required above 600°C. The temperature is measured with a repeatability of $\pm 0.1^\circ\text{C}$.
- Pans of Al, Cu, Au, Pt, and graphite are available and need to be chosen to avoid reactions with samples.
- Atmospheres: nitrogen, air, oxygen, argon, vacuum, controlled mixed gases.
- Sample size: from 0.5mg to 100mg.
- Used to determine the thermal properties of plastics, adhesives, sealants, metal alloys, pharmaceutical materials, waxes, foods, lubricants, oils, catalysts, and fertilizers

Applications of Differential Scanning Calorimetry

- Metal alloy melting temperatures and heat of fusion.
- Metal magnetic or structure transition temperatures and heat of transformation.
- Intermetallic phase formation temperatures and exothermal energies.
- Oxidation temperature and oxidation energy.
- Exothermal energy of polymer cure (as in epoxy adhesives), allows determination of the degree and rate of cure.
- Determine the melting behavior of complex organic materials, both temperatures and enthalpies of melting. can be used to determine purity of a material.
- Measurement of plastic or glassy material glass transition temperatures or softening temperatures.
- Determines crystalline to amorphous transition temperatures in polymers and plastics and the energy associated with the transition.
- Crystallization and melting temperatures and phase transition energies for inorganic compounds.
- Oxidative induction period of an oil or fat.
- May be used as one of multiple techniques to identify an unknown material or by itself to confirm that it is the expected material.
- Determine the thermal stability of a material.
- Determine the reaction kinetics of a material.

- DSC can also be used to measure glass transition temperatures, melting temperatures, crystalline phase formation temperatures, and crystalline to amorphous transition temperatures.

ASTM Test Methods

- ASTM E793 - Standard Test Method for Enthalpies of Fusion and Crystallization by DSC
- ASTM E794 - Standard Test Method for Melting and Crystallization by DSC
- ASTM E928 - Standard Test Method for Determination of Purity by DSC
- ASTM E1356 - Standard Test Method for Glass Transition Temperatures by DSC

3) Thermo-mechanical Analysis (TMA) Technique

The TMA uses interchangeable probes at varied loads to make a number of measurements, including the softening temperature or glass transition temperature, tensile modulus, compression modulus, coefficient of thermal expansion (CTE), melting temperature, crystalline phase transition temperature, crystalline to amorphous transition temperatures, and creep under load, by measuring the change of a dimension of a material. Note that the thermal expansion of a material may not be linear.

- Samples in the form of plugs, films, powders, or fibers, are compressed or held in tension by a probe assembly.
- Capable of testing polymers and plastics, metals, glasses, inorganics, composite materials, IC packages, semiconductors, small devices, adhesives, sealants, potting compounds, PCBs, and coatings.
- Temperatures can range from -70°C to 320°C.
- Sample dimensions: a maximum of 25 mm in height and 9.5 mm in diameter; a minimum of 0.1 mm thick and 1.5 mm in diameter, an ideal thickness being 1-4mm. Taller samples should have small lateral dimensions, so the sample interior temperature will not differ substantially from the surface temperature.
- The applied load can range from 0-100 g.
- The change of dimension should be greater than 2×10^{-3} mm/°C.

ASTM Test Methods

- ASTM E228 - Standard Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer
- ASTM E831 - Standard Test Method for Linear Thermal Expansion of Solid Materials by TMA
- ASTM E1545 - Standard Test Method for Assignment of the Glass Transition Temperature by TMA

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