UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION ON THE SUITABILITY OF PLASTIC BOTTLE MATERIAL AS 3D PRINTER FILAMENT.

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) with Honours.

by

MUHAMMAD SYAHMI BIN ZAINAL KIFLI
B071410326
941220-07

FACULTY OF ENGINEERING TECHNOLOGY
2017

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **INVESTIGATION ON THE SUITABILITY OF PLASTIC BOTTLE MATERIAL AS 3D PRINTER FILAMENT.**

SESI PENGAJIAN: **2017/18 Semester 1**

Saya **MUHAMMAD SYAHMI BIN ZAINAL KIFLI**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

_____ _____

Alamat Tetap:

No 15, Lorong DJ 12,

Taman Desa Jaya 2, 26400,

Bandar Jengka, Pahang

Tarikh: _____

Cop Rasmi:

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "**INVESTIGATION ON THE SUITABILITY OF PLASTIC BOTTLE MATERIAL AS 3D PRINTER FILAMENT.**" is the results of my own research except as cited in references.

Signature : …….

Author's Name : ……

Date : ……

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Refrigeration and Air-Conditioning System) with Honours. The member of the supervisory is as follow:

……

(Project Supervisor)

ABSTRAK

Tujuan kajian ini dijalankan adalah untuk membina filamen mesin pencetak 3D (tiga dimensi) menggunakan bahan buangan botol plastik. Kajian ini dilakukan dengan mengambil kira beberapa faktor seperti jenis botol minuman terbuang, suhu cairan botol minuman, kekuatan dan kekasaran permukaan produk yang dihasilkan. Terdapat tujuh jenis botol minuman atau plastik polimer yang sering diguna-pakai seluruh dunia. Namun kajian ini hanya memfokuskan kepada penghasilan filamen 3D menggunakan botol jenis High Density Polyethylene (HDPE). Penyataan masalah yang merujuk kepada kajian ini adalah lambakan bahan buangan daripada jenis botol minuman plastik dan tidak boleh mereput dengan mudah. Kaedah kitar semula yang sedia ada memerlukan kos yang tinggi kerana melibatkan pelbagai proses dan ianya tidak mesra alam. Objektif kajian ini adalah untuk menyediakan filament menggunakan bahan buangan botol plastik jenis HDPE. Seterusnya, adalah untuk menganalisis produk 3D yang dihasilkan menggunakan filamen yang dibuat. Objektif kajian yang terakhir adalah untuk menguji kesesuaian produk yang dihasilkan menggunakan filamen dengan beberapa jenis ujian seperti ujian kekuatan tegangan dan juga kekasaran permukaan. Cara penghasilan filamen ini adalah dengan menghancurkan bahan buangan plastik botol kepada serpihan kecil. Kemudian, serpihan tersebut akan dimasukkan kedalam alat "*filament extruder*" untuk menghasilakan filamen. Filamen yang dibuat kemudian akan digunakan oleh mesin pencetak 3D untuk mencetak produk 3D.

Kata kunci: botol plastik, High Density Polyethylene (HDPE), kitar semula, filamen 3D, mesin pencetak 3D.

ABSTRACT

The purpose of this research is to develop 3D printer filament using plastic bottle waste. This research is done by taking a few factors such as type of plastic bottle, plastic bottle melting temperature, strength and surface roughness of produce product. There are seven types of plastic polymer that popularly used around the globe but this research only focusing on developing 3D filament using High Density Polyethylene (HDPE) bottle. The problem statement that bring to this research is the excess volume of plastic bottle that stuck on landfills and cannot be dispose easily. The currently recycling method is high cost because its involve many process and not eco-friendly. The objective for this research is to prepare the 3D filament using plastic bottle waste HDPE type. Next objective is to analyze the 3D product that make from produce 3D filament. Last objective is to test the suitability of produce product using several tests such as tensile strength and surface roughness. The process to produce the 3D filament starts with shredding the plastic bottle waste into small fragments. Then, the fragments are feed into filament extruder to produce 3D filament. The produce filament then used on the 3D printer to print the 3D product.

Keywords: Plastic bottle, High Density Polyethylene (HDPE), Recycle, 3D filament, 3D printer.

DEDICATIONS

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time. Their sacrifice throughout my life had inspired me from the day I learned how to walk, read and write until what I have become now. I cannot find the appropriate word to describe my appreciation for their devotion, support and faith in my ability to achieve my dreams. They keep on supporting me and give me motivation to achieve my dreams. Lastly, I would like to send my gratitude to any person that contributes to finishing my Final Year Project whether it is directly or indirectly. I would like to acknowledge their supports, comments and suggestions which is are crucial for the successful completion of this study.

ACKNOWLEDGMENTS

First and foremost, all praise to Allah the almighty for giving me the strength, patience, health, knowledge and fortitude to successfully complete this Final Year Project report in the given time. I also would like to thanks to my parents for their support and motivate me to finish my Final Year Project. I also grateful to the master's degree student Arzadtul Ruziya binti Zolkaply and Muhammad Afdhal bin Nazhan for teaching me and give guidance to me throughout my Final Year Project progress. I would like to give my deepest appreciation to my supervisor, Madam Noor Saffreena Binti Hamdan for his encouragement, comments, guidance and enthusiasm through thick and thin until the completion of this project. This report might be impossible to complete without all your help. Last but not least, thank you to everyone that directly and indirectly involved in helping me finishing this Final Year Project. Thank you.

Table of Contents

List of figure

List of table

CHAPTER 1

INTRODUCTION

1.0 Introduction

Introducing the Bachelor Degree Project (BDP), this chapter is written about this project tittle which is "Investigation on the suitability of plastic bottle material as 3D printer filaments". This investigation is focusing on creating an eco-friendly filament which is produced from recycled plastic waste.

1.1 Background

There are many organization out there that focused-on recycling plastic bottle. However, the uses of plastic bottle have rapidly increasing years by years due to their ease of manufacture and low cost. The disposal process of plastic bottle is challenging because high amount of plastic is being accumulate. Organizations now are faces with the growing problem due to its very low biodegradability and it also comes in high quantity.

The largest components of plastic packaging or bottle waste is Polyethylene terephthalate (PET) following by high density polyethylene (HDPE) and polystyrene. These 3 types of plastic packaging are domination the world usage.

Recently, Plastic waste is one components which became a major research issue due to its possibility of disposal in many ways. But, this study is focusing on using it as 3D printer filaments. This is another way to use it again and recycling it

besides reusing it. Nowadays, scientist is recycling plastic waste in concrete since it has long service life and widely used which is the plastic waste is removed from the waste stream for a long period of time.

Plastic has its own properties which is suitable for using it as 3D filaments such as durable and corrosion resistant, it also a good isolation for cold, heat, and sound, has long lifetime and light weight. Therefore, in this research, recycling high density polyethylene (HDPE) and produce 3D filaments is proposed to realize the recycling process of polyethylene is green engineering forming technology. Moreover, it will be used in industrial and reducing the quantity of plastic waste around the world.

The process to recycling plastic waste into 3D printer feedstock or filaments is start with collection of plastic waste. Type of plastic waste that can be uses is high density polyethylene (HDPE), Polyethylene terephthalate (PET), Polyvinyl chloride (PVC), and other suitable plastic type. There are 7 types of plastic packaging but only some of them is suitable to recycling process because certain factor such as its density and contamination in plastic. After the collection process is done, the plastic packaging waste must be cleaned from contaminant to prevent defective in it physical properties. If the plastic packaging waste is bottle, the label on the bottle must be removed because the only material required is the plastic itself.

Shredding process then take place to shred the bottle into small pieces. The shredding bottle then enter the filament extruder machine and leaving the machine as 3D filaments. At first, the machine is only using to extrude the raw high-density polyethylene (HDPE) and form 3D filaments. But, this investigation is about the suitability of plastic packaging waste as 3D filaments.

Finally, the produced filaments then take certain test to proving that the plastic waste packaging is suitable to be 3D filaments and can be used in 3D printer machine. The test that take place in this investigation is surface roughness test and tensile strength. Surface roughness test is conducted using manual test by comparing the produce product of raw HDPE filament and recycling HDPE filament. The tensile strength test then conducted using tensile strength machine which pull the one end and another end of the produce product.

1.2 The purpose of the research

The purpose of this research is to investigate the suitability of the plastic packaging or bottle into 3D printer filaments and create the 3D filament. High density polyethylene (HDPE) is characterize as relatively stiff with high tensile strength compare to the other polyethylene based material (American Chemistry Council, 2007). So, the HDPE is the most suitable material to produce filament and it is easy to obtain as this research is conducted by using plastic packaging waste such as plastic bottle. There are many commercial products in market that using HDPE as their plastic packaging.

There are many types of 3D filaments that currently used such as polylactic acid (PLA), Acrylonitrile Butadiene Styrene (ABS), copolyester (PETG) is upgrade version of polyethylene terephthalate (PET), polyamide or known as Nylon, and others. These materials have their own characteristic and physical properties. So, this research is conducted to test whether this type of material (HDPE) are suitable to use as 3D filaments of vice versa.

By the end of this research, a 3D printing product is produce and the surface roughness and tensile strength test is conducted compared to the 3D product that produce using current market filament. The process to produce it and testing on the product will be done to assure it suitability as 3D printer filament.

1.3 Problem statement

One of the best option in the solid waste management is to recycle it to reduce the impact present by post-consumer packaging plastic waste (Mwanza and Mbohwa, 2017). The prior studies show that the best option to manage solid waste is to recycle. Nowadays, researcher is finding many ways to recycling solid waste such as plastic waste to preserve the earth and reduce the greenhouse effect. This research is conducted to find another way to recycling plastic waste and developed something that can reduce the cost of recycling process.

There are many plastic wastes that cannot be dispose and stuck on the landfills. To overcome this problem. Further investigation is performed to create more ways to recycling plastic waste and forming green engineering technology and helping to preserve the earth. Hence, that's why this study has been conducted.

1.4 Objective and scope

Based on the research title "Investigation on the suitability of plastic bottle material as 3d printer filaments", the objective below are pursued.

a) To determine the suitable parameter for extruding process.
b) To test whether it is suitable to use as 3D printer filaments by printing it on open sources 3D printer.
c) To comparing the mechanical properties of 3D product produces from recycled HDPE filament and ABS filament using tensile strength test.

This study focused on the recycling process of high density polyethylene (HDPE) plastic bottle into 3D printer filaments. The scope in this study is HDPE plastic bottle, 3D filaments, and testing which is bending test and tensile strength test.

1.5 Proposed solution

Recycling is the best method to carry out this plastic waste management problem. But, recycle has many ways to done it such as, reusing it, reducing it and recycling it into another object. So, this study chooses the method of recycling it into another plastic thing which is 3D printer filaments. Nowadays, 3D filaments are high demand from the industry and for educational purposes. When recycling plastic waste into 3D filaments, the cost to create this filament is also reduce and reducing the plastic pollution.

The further steps on how the 3D filaments is developed as well as the billing of material will be discussed in chapter 3 (methodology) of this report.

1.6 Summary

Based on the raw material that will be used in this investigation, all material is easily obtained because the plastic waste can be collected free from anywhere. Shredding machine and filaments extruder also are available in university laboratories and widely use around Malaysia. Here, the temperature control play an important role as the plastic material has its own melting point. So, the further study need to know how to control the temperature to melting the plastic waste and not affect the earth pollution.

The 3D filaments produce then will be printed into 3D printed product and will take the test to prove its suitability for 3D printer usage. The test on the 3D printed product is bending test and tensile strength test because these 2 types of characteristic will affect the product if has any defect and will make this filament are not suitable for use.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this chapter, there are few briefing from a few journals and some other resources such as magazine, books, report and others on how the recycling plastic bottle into 3D filaments process, HDPE plastic bottle type properties, and some testing explanation.

2.1 Plastic polymers

Plastics are natural materials, that is, they are made from synthetic mixes containing carbon. These mixes are connected together to frame atoms known as polymers (Guide, 2013). Today, a lot of what we consider as plastics are engineered materials, which came from the results of chemical synthesis. Polymers have two different types which is thermoplastic and thermosetting. Each type of polymers has their own properties, molecular weight, processing method and synthesis. These two types of polymers are differentiated on their behavior by the presence of heat. Thermoplastic has lower melting point which is they can melt in low temperature compared to the thermosetting which is can withstand the high temperature without losing its rigidity.

2.1.1 Thermoplastic

Thermoplastic is a class of polymer, which can be effortlessly dissolved or softened by applying the high temperature to recycle the material. Thermoplastic have covalent bond interaction between monomer molecules. Furthermore, it has connection between polymer chain by weak van der wall interaction (Cowie, J. M. G.; Polymers: Chemistry and Physics of Modern Materials, Intertext Books, 1973). Figure below shown the interaction between molecules.

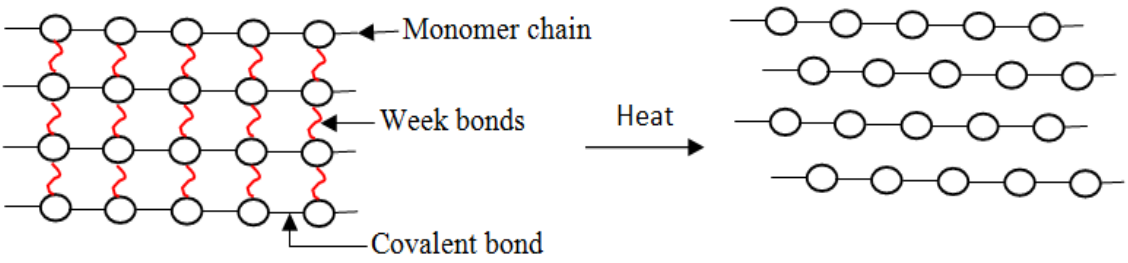

Figure 1: Thermoplastic polymer change into softened state.

(source:< http://pediaa.com/difference-between-thermoplastic-and-thermosetting-plastic>, 2017)

The softened thermoplastic can be placed in the mold and then cooled to produce desired shape. Therefore, the advantages of this polymers are easily recycled and remodel because each time it reheated it can change it form into desired shape. The plastic bottle that consumer use nowadays is polymers such as HDPE and PET plastic bottle.

2.1.2 Thermosetting

Thermosetting has superior properties such as high warm solidness, high inflexibility, high dimensional strength, impervious to crawl or twisting under load, high electrical and warm protecting properties, and so forth. The thermosetting plastic has three-dimensional connection in covalent bond linked together between atoms and this is highly cross-linked polymers. This bond shows the resistance of the thermosetting plastic to high temperature which provide greater thermal stability compared to the thermoplastic. Therefore, this type of polymer cannot be recycled and reformed. The figure 2.1.2 shows the change between the molecules when the high temperature is applied.

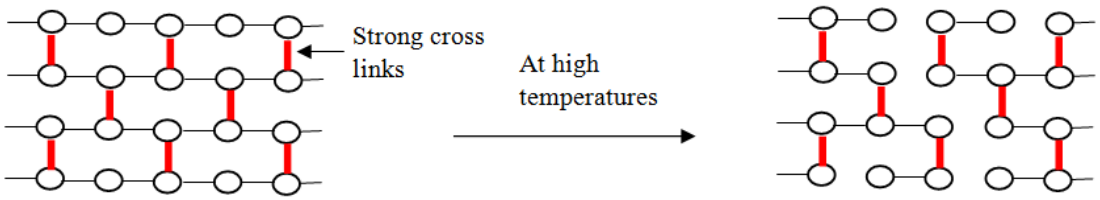

Figure 2: Thermosetting plastic at high temperature bond.

2.2 Plastic bottle

Plastic bottles are a significant part of the municipal waste. They have exceptional significance because of their low thickness to volume proportion. Also, they are synthetically steady since they are non-biodegradable materials (i.e. the biodegradation process is to slow). This implies that plastic waste will be discernable for quite a long time or years, and waste will stay in landfill destinations for a considerable length of time without debasing (Tachwali, Al-Assaf and Al-Ali, 2007). This means that plastic bottle can bring harm to the environment and affect the long term environmental problem. Plastic bottle can be sorted into various classes considering their synthetic resin, transparency or potentially shading. There are seven plastic sorts based on chemical composition which is (1) Polyethylene Terephthalate (PET), (2) High Density Polyethylene (HDPE), (3) Polyvinyl Chloride (PVC), (4) Low

Density Polyethylene (LDPE), (5) Polypropylene (PP), (6) Polystyrene (PS) and (7) other plastics (Hammaad, 2005). Plastic bottle waste is everywhere and figure below show the quantity of plastic production around the world by region.

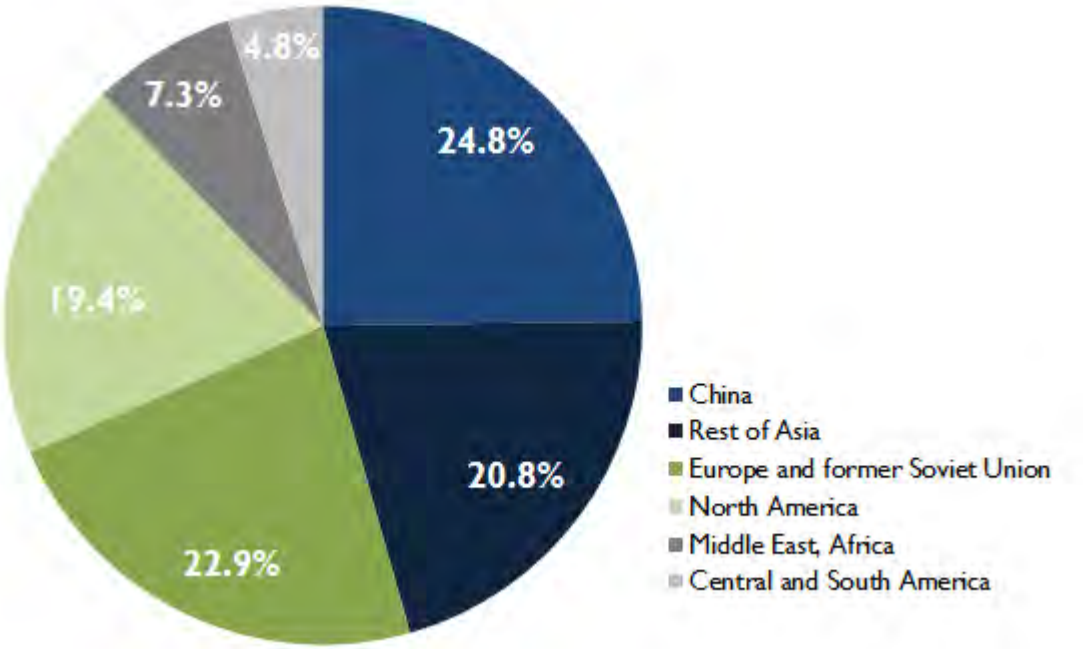

Figure 3: World production of plastic materials by region on 2013.

(source: < http://www.worldwatch.org/global-plastic-production-rises-recycling-lags-0 >)

The quantity of plastic material produced is increasing every year because of the industries and clients demanding it. The figure show that china is dominating the plastic industry with 24.8 % of world plastic production following by Europe and former Soviet Union with 22.9 % and the third biggest production is from Asia country. China also an Asia country and it means that Asia is the biggest plastic producer.

2.2.1 Polyethylene Terephthalate (PET)

PET is abbreviation for Polyethylene Terephthalate from one of polymer groups out of seven. Polyethylene terephthalate (PET) has turned into the greatest bundling material worldwide for water and soft drinks bottles (Welle, 2011). The PET is one of the favorable polymers used worldwide because of its material properties also the unbreak ability and the low weight of the bottles contrasted with glass bottles of a similar filling volume. The amounts of PET plastic bottle usage around the globe are increasing and it may harm the earth environmental and green house effects. worries over environmental issues, asset preservation, and the advancement of recuperation innovation, recycling has turned into a key calculate the production network of PET bottle. Recycling of PET bottles not just can possibly monitor petroleum derivatives; however, it can likewise be reducing energy usage and greenhouse effects (Smithers Pira organization, 2012; Coelho, 2011).

PET plastic bottle mostly has number 1 logo label using coding system from U.S. and use in various country around the globe (D20 Committee, 2013). A press report published on 10 February 2003 in source weekly by Lilya says that there is possibly toxic substance migrate from PET plastic bottle into drinking water when reusing it. From this report, PET plastic bottle is not safe to reusing it again and again because of toxic presence. However, the PET plastic bottle cannot bear the high temperature of boiling water.

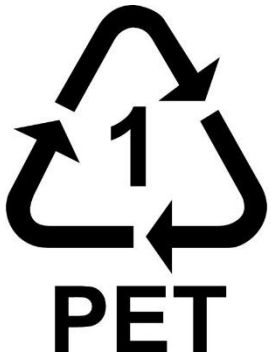

Figure 4: Recycled logo for PET plastic type.

2.2.2 High Density Polyethylene (HDPE)

HDPE stands for High Density Polyethylene which is some of the polymers type. In construction industry, recycled HDPE fibers can be instrumental and creating a new value chain also contributing to environment performance. This is suggested by all the findings from (Pe??i?? *et al.*, 2016). It enough to tell the world that HDPE plastic bottle is safe to use again and again or reuse it. HDPE plastic bottle has number 2 recycle logo which is considered as safe to use and low risk of leaching (Natural society 2013). All number 2 recycled logo is high density polyethylene (HDPE) type of plastic and mostly found in milk jugs, bleach bottle, juice bottle toiletries, butter tubs and many more.

Figure 5: Recycle logo for HDPE plastic type.

(Source: <https://ecosumo.wordpress.com/tag/no-2-recycling-symbol> June, 2009)

There are large quantity of readily available post-consumer waste of HDPE plastic and can create new value in circular economy through the production. From this waste stocks through one of the industrially established extrusion process, the recycled HDPE fibers could be most economically produces (Pe??i?? *et al.*, 2016). This statement show that there are many HDPE plastic waste ending at garbage disposal center and need costly process to dispose it. Recycling it are the best way to solve this world issued problem. Recycling HDPE plastic waste has advantages since it is widely used and has long life service, which means it need long time to consume it and dispose it. Moreover, recycling HDPE into 3D filaments may improve the production of 3D printer technology which is currently using raw material to produce its filaments and this technology may growth faster than before.

2.2.3 Polyvinyl Chloride (PVC)

PVC is broadly used in the cable industry, majority of them contain plasticizer or other natural added substance in order to enhance its flexibility (Suresh, Mohanty and Nayak, 2016). According to Mersiowsky et al., 2001 The phthalic acid esters (phthalates) were mostly used in the PVC mixtures because of its excellent plasticizing properties. PVC also has excellent transparency, chemical resistance, enduring stability and good stable electrical properties. PVC also used to make plastic container such as Tupperware, bottle, caps and others. PVC are widely used to make pipe which is known as PVC pipe and broadly used on building, residential area and others as water pipe or electrical wire insulation. PVC has recycled codes 3 as shown below.

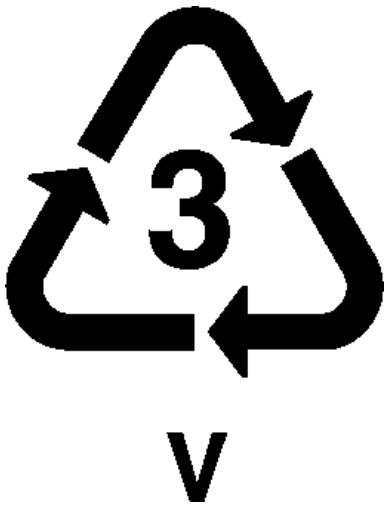

Figure 6: Recycle logo for PVC plastic type.

Flexible to firm plastic that is transparent to yellowish in its usual state. Polyvinyl Chloride is called PVC, but it is also regularly known as vinyl. So, the recycling code for PVC just uses the letter V.