Extract Methane from PVC by Recycle Process

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Abstract- **Polyvinylchloride (PVC) [-(-CH2 -CHCl-) n-] is one of the three most important polymers currently used worldwide. This is because PVC is one of the cheapest polymers to make and has a large range of properties so can be used to make hundreds of products. Plastics are high molecular weight organic materials, which can be molded into any shape when subjected to heat and pressure in the presence of a catalyst. Essential for this success are low life-cycle costs, longevity, and the recyclability of these high-quality products. Current methods of recycling of poly vinyl chloride (PVC) are highly risky & skill oriented and produces highly toxic gases such as chlorine which is a potential carcinogen. The result of the defined mechanical recycling process is to minimize the chlorine level from 90% to 10% and to produce methane gas, which is an alternate fuel. The percentage of methane in the residual gas of this process will be studied using a gas analyzer, the fuel properties, heat capacity, flash point and fire point will be experimentally studied and the efficiency of this process will proved. Our aim is to recycle the PVC and to obtain an alternate fuel. The produced gas (Methane) can be utilized for domestic cooking, for which there are some modifications required for burner and gas stove, which will be studied and analyzed in this project.**

Index Terms- **PVC, Recycle, Methane, Chlorine, Alternate fuel.**

I INTRODUCTION

Plastics are high molecular weight organic materials, which can be molded into any shape when subjected to heat and pressure in the presence of a catalyst. Plastic materials show the property of plasticity. Under the characteristics of plastics they are classified as following two types,

1. Thermoplastics
2. Thermosetting plastics

Thermoplastics

As the temperature is raised above the melting point, the secondary bonds weaken, making it easier to form the plastic into any desired shape. When polymer is cooled, it returns to its original strength and hardness. The process is reversible. Polymers that show this behavior are known as thermoplastics.

Examples: PE, PVC, PS, PP, PAN, cellulosic.

Thermosetting Plastics (Thermosets)

Thermosetting plastics are cured into permanent shape and cannot be re-melted to the flow able state that existed before curing, continued heating for a long time leads to degradation or decomposition. This curing (cross-linked) reaction is irreversible. Thermosets generally have better mechanical, thermal and chemical properties. They also have better electrical resistance and dimensional stability than do thermoplastics.

Examples: Bakelite, silicones, polyesters.

POLY VINYL CHLORIDE (PVC)

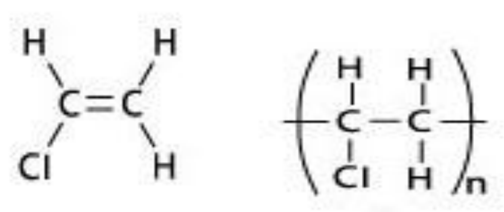
Poly (vinyl chloride), commonly abbreviated PVC, is the third-most widely produced polymer, after polyethylene and polypropylene. PVC is used in construction because it is more effective than traditional materials such as copper, iron or wood in pipe and profile applications.

PVC is nontoxic odorless white powder. With features of flame retardant, chemical corrosion resistance, comprehensive mechanical, products transparency, electric insulating and easy processing, PVC can be used to produce section, PCPO, tubing and pipe-fittings, board, sheet, cable sheath, hard or soft tube, blood transfusion equipment and membrane.

Approximately 70% of PVC produced is used in Europe to manufacture rigid products such as window profiles and pipes, which are distinguished by their longevity and weather resistance. The remaining 30% covers soft applications. Plasticizers provide PVC with special properties of use similar to those of rubber. This naturally hard material becomes flexible and elastic through plasticizers. Additives are added to polymers in order to obtain or improve certain properties such as strength, stiffness, color, resistance to weather and flammability. Plasticizers are added to obtain flexibility and softness, most common use of plasticizers is in PVC. Ultraviolet radiation (sunlight) and oxygen cause polymers to become stiff and brittle; they weaken and break the primary bonds. A typical treatment is to add carbon black (soot) to the polymer, it absorbs radiation. Antioxidants are also added to protect against degradation. Fillers such as fine saw dust, silica flour, calcium carbide are added to reduce the cost and to increase harness, strength, toughness, dimensional stability. For more than 50 years, PVC has been very successful throughout the world. Today, this versatile material is one of the most important plastic materials recognized internationally and proven on the market.

Chemical Composition

The vinyl chloride molecule is C_2H_3Cl



Vinyl Chloride Monomer (VCM) &Polyvinyl Chloride Polymer

Properties

A highly versatile polymer, PVC is compatible with many additives. It can be plasticized to make it flexible for use in flooring or un-plasticized (PVC-U) for use in building applications and window frames.

Mechanical properties

The mechanical properties enhance with the molecular weight increasing, but decrease with the temperature increasing. The mechanical properties of rigid PVC (uPVC) are very good; the elastic modulus can reach to 1500-3,000 MPa. The soft PVC (Flexible PVC) elastic is 1.5-15 MPa. However, elongation at break is up to 200% -450%. PVC friction is ordinary, the static friction factor is 0.4-0.5, and the dynamic friction factor is 0.23

Table-1 Physical properties of PVC.

Physical Properties	Value
Tensile Strength	= 2.60 N/mm^2
Notched Impact Strength	= 2.0 - 4.5 Kj/m^2
Thermal Coefficient of Expansion	= 80 x 10^{-6}
Max. Continued Use Temperature	= 60^oC (140 ^oF)
Melting Point	= 212 ^oC (413 ^oF)
Glass Transition Temperature	= 81^oC (178 ^oF)
Density	= 1.38 g/cm^3

Uses

PVC is the most widely used polymer for cables production in Europe. It is mainly dominant in the low voltage and some specialist applications.

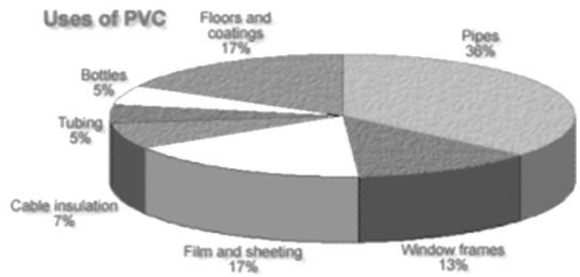


Fig-1 Applications of PVC.

II. PROCEDURE AND METHODS

A. PVC Recycling

Used PVC products are too good to throw away. The European PVC industry has organized a recovery system for the most important PVC products in order to save valuable resources and has set ambitious goals for the future Review Stage.

The Environmental Protection Agency calculates that 910,000 tons of PVC wastes are generated annually but less than a quarter of 1 percent is recovered for recycling [1]. PVC is chemically manipulated during production to achieve uses from household fabrics to construction piping. The additives used in these manipulations and PVC's inherent chlorine content complicate recycling processes for this plastic [2].

B. Environmental Concerns

Chemical additives and heavy metal content have deemed PVC to be a particularly polluting form of plastic, both when incinerated and when buried in landfills. The material has been found to leak chlorine, carcinogens and other toxic chemicals into the soil and air over time within landfill or incineration disposals. These pollutants have led many governments to focus policies on the reduction of PVC production and usage, as well as to research healthier alternatives to PVC's harmful additives and healthy recycling methods for PVC [2].

C. Postindustrial Recycling

Most PVC with recycled content has been mechanically recycled from industrial scrap material [2]. Industries can collect PVC from a single source, increasing recycling efficiency. The variety of additives in mixed PVC sourcing can hinder processing due to potential contamination, which can result in unsafe working environments and unusable products [2]. Because industries can bypass the intensive sorting required of mixed batches, many have begun to run product-specific collection or buy-back programs. These programs allow manufacturers to recycle increasing amounts of postconsumer PVC along with postindustrial material [3].

Methods and Technology:

1. Collection: About 50 collection points have been set up all over the country where used pipes can be delivered free of charge. In parallel, rental containers have been installed at specific customers. Container rent and transportation costs are charged to the customer (about 100 Euro per ton on an average).
2. Sorting and mechanical Treatment: There exists one recycling plant at the company Wavin. The mechanical treatment process consists of the following major unit operations:
3. Manual sorting line, there PP- and PE-pipes are separated from PVC pipes; this is possible due to the different colors (there is no labeling for different plastic types);
4. Shredder unit;
5. Separation units for rubber, Fe-metals and non-ferrous metals;
6. Sieve where sand and a coarse PVC fraction which is returned to the shredder are separated.

Process

By increasing the number of PVC while heating, 76% of chlorine is produced. Subsequent reduction of chlorine from PVC is done by mixing of NH_4Cl and NaOH into it. Finally we get 90% of Methane and the remaining 10% will be chlorine gas. This Methane gas also contains (1-5%) small amount of chlorine gas. But it will not affect Human beings. The Methane gas (90%) thus produced by the above process can be used as cooking gas.

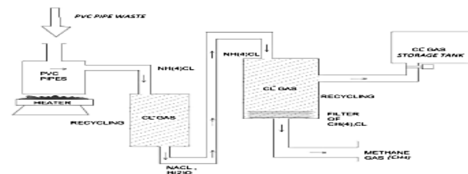
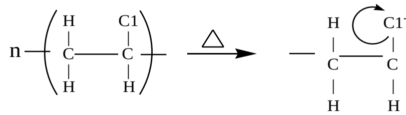


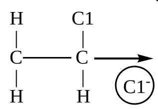
Fig-2 Design diagram of methane production

Poly Vinyl Chloride- Heating Reaction

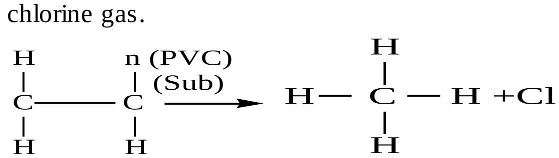
To heat Poly vinyl Chloride waste pipe and to easily removed chlorine gas from ploy vinyl chloride wastage.



This chlorine gas is highly harmful one.



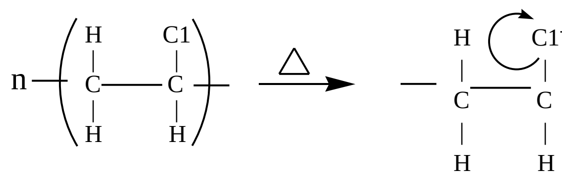
On heating PVC it will burn faster and releases chlorine gas.

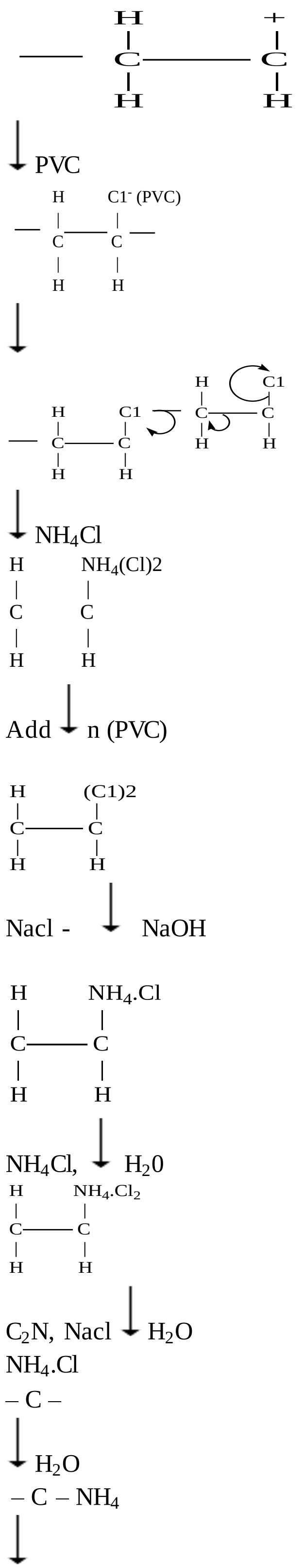


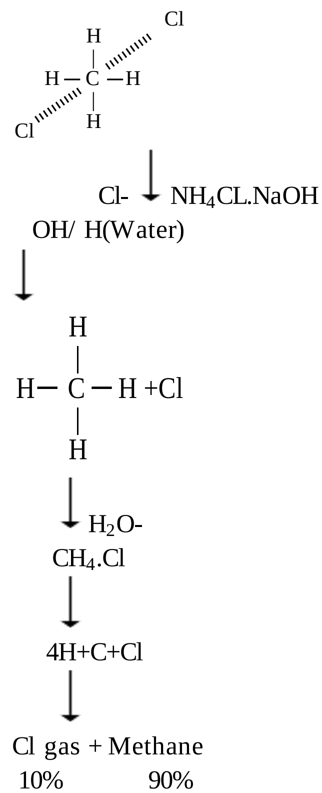
The chlorine produced during this process is about 98% and it will affect the people when inhaling. Prolonged exposure to chlorine will lead to liver failure and cancer. The remaining 2% of end product is mixed with number of PVC to get methane gas(alternative fuel) which will be used for the cooking purpose. Methane consists of four hydrogen atoms and one carbon atom.

Methane-Production

(To reduce chlorine gas from PVC waste)







PROCEDURE:

The following procedure clearly explains about results of methane gas from PVC waste.

Procedure

1. Polyvinyl chloride was de-chlorinated at 380°C and 30 min in nitrogen gas ventilating. Nickel, NH4CL, KOH or NaOH was used for the gasification catalyst. To add the following chemical solution during this process.
   Chemical composition:
   2N NaOH = 8 ml
   1N NH4CL = 5 ml
   H2O (water) =20 ml
2. The plastic, distilled water and catalyst were loaded into the reactor.
3. During this step we get only 2% of methane gas product and 98% of chlorine product.
4. By increasing the number of PVC while heating, 85% of chlorine is produced.
5. Subsequent reduction of chlorine from PVC is done by mixing of NH4CL, NaOH and also the following steps are followed.

6. It took about 15min for the reactor to increase from the room temperature to the setting reaction temperature around 700°C.
7. After reaching the reaction temperature, small amount of distilled water, NH4CL, and NaOH was added into the reactor using a high pressure pump in order to adjust the reaction pressure. During this step the chlorine level from 85% to 10% gradually reduced.
8. After a given reaction time, the furnace was turned off and opened, and the reactor was cooled quickly with the electric fan.
9. The gaseous product was collected into a sampling bag and analyzed using gas chromatographs equipped with thermal conductivity detectors. Finally we get 90% of Methane and the remaining 10% will be chlorine gas.
10. This methane gas also contains (1-5%) small amount of chlorine gas. But it will not affect the human beings.
11. The methane gas thus produced by the above process can be used on the cooking gas.

III RESULTS AND DISCUSSION

Flash & Fire Point Study

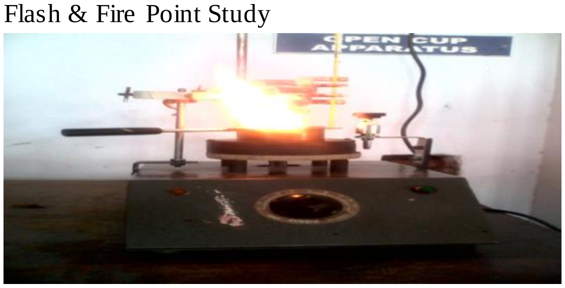


Fig-4 Experimental images for open cup apparatus

Result from Experiment:
Flash point of produced gas = 30°C
Fire point of produced gas = 35°C

Effect of heat on PVC

The following graph depicts the percentage of PVC plastic waste, which is directly propositional to percentage of methane gas produced.

Table-2 Effect of heat on PVC – Experimental results

S.NO	PVC waste (%)	Chlorine gas removal (%)	Adding solution doing process (%) (chemical solution)	Methane production (%)
1.	10%	98%	-	2%
2.	50%	85%	NH4CL	15%
3.	n(PVC) n(PVC)	63.55% 30%	NH4CL,NaOH NH4CL,NaOH	36.45% 70%
4.	n(PVC)	10%	NH4CL,NaOH,H2O, Alcohol	90%

IV. CONCLUSION

Plastics are very useful because of their lighter weight, extreme durability, hygiene properties for food packaging and less expensive to produce. However plastics are non-degradable and it contains many toxic additives like polyvinyl chloride, polycarbonates which would leach out into the food causing many diseases. The recycling technologies like pyrolysis, gasification processes are very useful for the production of valuable fuels and chemicals from waste plastics. However the products of above processes contain some poisonous gases and metals. So the best method of several recycling and reheating the plastic waste (PVC) and to produce alternate fuel (methane gas).

Thus this innovative method of PVC recycling not only reduces the percentage of chlorine from 90% to 10% and produces clean and green alternative fuel methane (CH4). This methane can replace the non-renewable fuel gas (or) LPG gas. Overall this process ensures a pollution free environment and an alternative fuel.

REFERENCES

1. Weinlein.R (1996)
a. Vergleichende Umweltanalyse von Thermoplast-Bauteilen aus Recyclat und Neuware; TU
b. Berlin, Schriftenreihe Kunststoff-Forschung No. 37, Berlin.
2. Prognos (1999)
a. PVC und Nachhaltigkeit, Köln.
3. Tno-Sofres conseil (1998)

a. Assessing the potential for post-use plastics waste recycling-predicting in 2001 and 2006
b. (Summary Report), study commissioned by APME, Brussels.
4. Totch.w:gaensslen,H.(1990)
a. Polyvinylchlorid. Zur Umweltrelevanz eines Standardkunststoffes, Köln.
5. U.S. Environmental Protection Agency: Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Plastics