23rd WEDC Conference Durban, South Africa, 1997
WATER AND SANITATION FOR ALL: PARTNERSHIPS AND INNOVATIONS

Occupational health impact of plastic recycling

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THE PRESENT PAPER is based on the preliminary observations on the plastic reprocessing industry in Bangalore, a Southern Indian city. Bangalore has approximately 300 plastic reprocessing units. Each unit employs on an average 5 people. An average recycling capacity of a reprocessing unit is a quarter ton a day. This amounts to 75 tons of plastic waste reprocessed in a day. Nearly, 60 per cent of the waste reprocessed in a day is directly procured from plastic processing and manufacturing industries and other institutions and rest, roughly 27 to 30 tons per day, is post consumer plastic waste.

Types of polymers reprocessed

Mainly, all varieties of Polyolefins i.e. Polyethylene-Low Density (LDPE), Polyethylene-High Density (HDPE), Polyethylene-Linear Low Density (LLDPE), High Molecular Polyethylene (HMPE), Polypropylene (PP); and Poly Vinyl Chloride (PVC) are the types of plastics reprocessed in Bangalore. In addition, PET is reprocessed by chemical recovery method in two different plants in other parts of India.

Process

First, waste is sorted as per the type of plastic. Mainly, visual methods of linking the scrap with its previous use is employed to determine the type of plastic. If still confused, the plastic is either broken or burnt to determines the type of plastic by fragrance. Float and sink methods to differentiate plastic on the basis of density is rarely used.

The uniform variety of plastic scrap is subsequently cut into flakes and fed into the high speed mixer with or without washing. Pigment in the form of masterbatch is mixed at this stage. Flakes are fed into extruder at high temperature and the cords thus generated are converted into pellets which are again extruded to be shaped in the final product. This method is employed to reprocess all varieties of PE and PVC. However, PP is first extruded into lumps which are ground and again fed into extruder to make pellets. Sometimes final product is made straight from the lumps.

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Origin

Physical environment

Grinding scrap is a noisy operation. Some times noise level may go up to 95 db. Small scale enterprises are often not designed for the reprocessing purpose. Adequately designed ventilation to quickly remove the gaseous products and heat is generally not present. Lack of space for easy movement makes it further congested.

Cleaning

Caustic Soda and other cheap detergents are used for cleaning. The flakes or chips are soaked in detergent for anywhere between 1 to 3 days. Before rinsing they are washed with hands. This operation would require a worker to keep her/his hands in soap solution for 6 to 8 hours a day.

Grinding

Major products of grinding are RPM (respirable particulate matter) and SPM (suspended particulate matter). Air quality monitoring[1] in one of the plastic reprocessing unit in Bangalore revealed RPM = 241 mcg/cu.m and SPM = 1491 mcg/cu. m.

Colouring

Pigments in powder form or concentrated pigments in capsule form known as masterbatch[2] are used. Commonly used colours are Titanium oxide (white), Thelocynine (green and blue), Scarlet City and Iron Oxide (red), Benzandine (yellow), and Cadmium (red) in addition to carbon black. Most of the colour pigments are complex organic compounds, usually with a metal chelate, which provides the typical colour. Metals present include Cadmium, Copper, Iron, Tin etc. Coloring at present is mainly done by masterbatches and hence dispersion powder elements are minimum.

Extrusion

Volatile matter is generated at two levels: during normal processing at elevated temperature[3] and during degradation[4] at abnormally high temperature. All plastics are subjected to varied degree of degradation during normal reprocessing temperature due to presence of contaminants[5], additives and pigments[6], inappropriate temperature control[7] and inferior type of machinery[8] used. Depending upon type of material, temperature and presence or absence of oxygen the gaseous matter include: HC, HCN, NO_X, SO_2, CO, CO_2, formaldehyde, and chlorinated gasses in case of PVC (Papaspyrides, 1996; Chanda and Roy, 1987; Williomson, 1992; Ingenieure, 1980; Mark, 1989).

Breaker plate[9] burning

The contaminants filtered by breaker plate during the process of extrusion are removed by burning the plate at

least once a day. Volatile products may contain saturated and unsaturated hydrocarbons in case of PE and PP; and hydrogen chloride, HC, coloured tars and suit in case of PVC in addition to products of heating (Crider and Holbrook, 1977).

Level of technology

- Presence of moisture in the extrudate in the extreme condition may lead to explosion[10].
- Overheating due to lack of automatic temperature control may lead to degradation and eventual clogging of delivery channel and subsequent release of volatile matter.
- Probability of electric short-circuit is high[8].
- heated barrel without protective casing may cause accidents particularly at the time of changing wire mesh[11].
- Degradation due to unscheduled power shut down[12].

Probable occupational health impact

In the absence of any statistical analysis, following description is to create a *prima facie* case and not the exact prediction of occupational health hazards.

Physical hazards

Physical hazards are many given the nature of technology used in the recycling sector. Lack of proper ventilation increases the susceptibility to exposure to toxic gases. Exposure to heat, lack of fresh air for continuously 8 hours can easily cause fatigue and erode immunity level.

Probability of accidents is very high. Explosion of extruder is not uncommon. Burns due to frequent contact with heated barrel are also common. Cuts and injuries due to cut pieces thrown out at high velocity while grinding is casually taken. Exposed electric wiring can even prove fatal. Cases that the hand of the worker was snatched away inside grinder while pushing the scrap are reported. Skin irritation, injuries and cuts at the time of washing and drying flakes are routine.

SPM and RPM

Smoke arising of heating and grinding processes comprise soot, fine dust and ash in a mixture of gases. Size of particles range from 0.5 to 100 micron particle size. Particles above 10 micron size do not enter human breath, between 5 to 10 micron size are retained in upper respiratory tract and particles less than 5 microns, known as respirable particulate matter reach lungs. 75 mcg/cu.m is the proposed higher limit for RPM in India. Typically, the city of Delhi and Madras contain 70 to 220 mcg/cu.m and 40 to 125 mcg/cu.m respectively (Agrawal, 1996).

In addition to the upper respiratory tract ailments, Respirable Particulate matter chemically loaded due to heavy metal contamination originated from pigments can affect pulmonary area of lung and in long run result in fibrosis, fever and oedema (Murdoch, 1993).

Carbon monoxide

The principle effect of Carbon Monoxide is on the red blood cell pigments which has higher affinity for CO than for Oxygen. This can lead to haemoglobin molecule bound to CO than to Oxygen known as Carboxyhaemoglobin. A 5 per cent Carboxyhaemoglobin level could result in with an exposure at 25 ppm for a full shift. Typically blood of a smoker contains 5 to 10 per cent of Carboxyhaemoglobin. At the level 10 to 20 per cent headache and beyond 20 per cent level severe headache, weakness, dizziness, dimness of vision and eventually nausea, vomiting and collapse occurs (Gnanmani and Kasturi Bai, 1996; Murdoch,1993).

Nitrogen dioxide and nitrous oxide

Both NO and NO_2 can produce inactive form of haemoglobin known as methemoglobin. Studies suggest that eye and nasal irritation could be observed after an exposure to nitrogen oxide of about 15 ppm, and pulmonary discomfort after brief exposure to 25 ppm. Short time period exposure to 25 to 75 ppm can cause pathological disorder. Exposure to 150 to 200 ppm of nitrogen could lead to gradual production of fatal pulmonary fibrosis (Gnanmani and Kasturi Bai, 1996).

Hydrocarbon vapour

It is a mixture of gases and may contain benzene, ethylene, formaldehyde, methane, propylene, propane etc. Even the trace amount of these gases can cause potent irritation in upper respiratory tract and at higher concentration difficulty in breathing and cough. Few of these gases are known carcinogens. For example, benzene interferes with formation of red blood cells in bone marrow and leukaemia occurs in some individual with long term occupational exposure. Ethylene oxide and formaldehyde are animal carcinogens and can cause similar effect in humans with chronic exposure, which may be very rare in case of reprocessing of plastic (Mark et al, 1989).

The product impact

Articles made of recycled plastic can have leaching out effect wherein the products of in service degradation may migrate to the matter coming in contact with it (Briston, 1974). The products of in service degradation may contain trace elements of pigments, additives, unplasticised material and scores of other elements, nature of which is largely unknown. Besides, few times extruded plastic becomes porous and serves as a breeding ground for bacteria. This may have serious manifestation if recycled plastic is used to store or transport edibles. For example, *Kodams* (water pots) made of recycled HDPE, sometimes three to four times recycled, has huge market in lower and middle income urban areas facing severe water shortage. They are not only used to fetch water but are also utilised to store it for drinking and cooking purposes.

A senior official of IPCL (Indian Petro Chemical Ltd), Bangalore branch admitted that use of *Kodams* made of recycled plastic for fetching and storing drinking water is not advisable.

Policy issues

Theoretically, reprocessing should have similar impact as processing and use of virgin plastic has. Nature and type of the technology employed for reprocessing seems to do more with occupational and environmental health impact than reprocessing *per se*. Simple technological improvement and proper process control can largely prevent environmental impact and also improve product quality. Standardisation of the process and technology should be developed in consultation with small scale plastic reprocessors.

Products made of reprocessed plastic needs greater attention. The Indian Standard Institution has developed specific Indian Standard for Moulded Briefcases, Packaging Material, Reflectors and Lighting-Fittings and Polyethylene Buckets made of reprocessed plastics. The adoption of the Indian Standard for the product manufacturing is nevertheless, completely voluntary. In fact very rarely the products made of reprocessed plastic comply with the Indian Standards. The standard should be made mandatory at least in case of packaging materials and products.

End notes

1 The study was conducted by Sriram Institute of Industrial Research, Bangalore, India. Samples for 8 hours were collected from a recycling unit when LDPE and later PP were reprocessed. SO_2 (11 mcg/cu.m), Nitrous Oxide (21 mcg/cu.m), CO (2916 mcg/cu.m), Hydrocarbons expressed as CH_4 (16 mcg/cu.m) and noice level (96.9 db) were other parameters monitored.

2 Masterbatch is a capsule of concentrated colors with certain additives: Silicon Dioxide for uniformity and handling ease, dispersing agents like easter and waxes and coupling agents like salts of Silicon and Titanium. These additives improve color mixing and have no impact on processing.

3 It involves the mechanical scission of polymer chain leading to rapid reduction in molecular weight. This has two manifestation, one, the polymer becomes more susceptible to degradation during reprocessing and second, its tensile strength is considerably reduced making subsequent product life shortened (Papaspyrides, 1996).

4 This is highly unpredictable part of polymer science. Various additives and other contaminants present may produce complex mixture of toxic and non-toxic matter in specific processing conditions which are largely unknown (Williomson, 1992).

Stability of the polymer against thermal degradation and chemical nature of thermal decomposition vary widely from one material to another. Stability of the polymer depends upon heat history it has been subjected to, the contaminants present and molecular weight. Each heating cycle makes it more prone to degradation unless the previous heat history (rate and intensity of heating and cooling) is repeated. First or second time recycled plastic contains fair amount of contaminants and that makes it more susceptible to degradation. Lastly, each heating cycle decreases average molecular weight which also has profound effect on its stability against degradation (Ohtani and Tsuge,1996). Hence, even under the normal conditions of reprocessing part of the plastic is subjected to degradation unless heat stabilisers are added, which are rarely added in case of reprocessing. Besides, there are low flow regions in the machine known as "hang up" zones where material is likely to be stuck up and degrade.

5 Various contaminants are present may be due to labelling content, packaging content, the products with which plastics come into contact during the service life, other polymers and additives. During in service use the plastic may be photodegraded and can form low molecular weight oxygenated products like aldehydes, acids, ketones, waxes etc. These low molecular weight impurities can lead to segregation at the time of reprocessing and further sensitise the reprocessed polymer to degradation (Salamone, 1996).

6 The pigments used are mostly based on inexpensive metal oxides that act as prooxidants at high temperature at the time of extrusion. Some of the pigments, for instance chromium based green pigment, can catalyse the thermooxidative degradation of HDPE when present even in trace quantities. Virgin PE is usually stabilised to prevent in service degradation, but with processing this antioxidants are consumed and these pigments may exert prodegradant effect (Mark, 1989). Since reprocessed Polyolefins are rarely stabilised the pigments further promote degradation when the product is subjected to heat, light and pressure in service.

7 There are two ways of temperature control generally employed: manual off and on of the heaters or cooling with water manually. Automatic temperature control systems known as Pyromatric temperature control are rarely used. The second system of temperature control wherein heating can be stopped for set timing, say 10 per cent or 20 per cent of the heating time, are also not commonly used as they are difficult to maintain.

8 Machinery used for reprocessing in Bangalore are by and large fabricated in local workshops or in the industry itself, in all likelihood from second-hand or discarded machinery and have bare minimum parts. Usually heaters and electrical wiring connected with barrel are exposed without any casing. The wiring is connected, in many cases, without even insulation tapes. In such case, proper design of the extruder screw to suit the type of polymer being reprocessed and automatic temperature control can be least expected.

Extruders are single screw type with or without increasing root diameter from feed to metering zones. Vented extruders, which can remove volatile matter in the early stage of extrusion and reduce chances of degradation and improve quality of product (Braun, 1971; Brydson, 1973) are rarely used as the cost of such machines are very high compared to the non-vented ones.

9 At the end of the melt zone in the extruder there is a breaker plate with wire mesh. It is a perforated disc of greater thickness and has several important functions. It helps to homogenise the melted material and holds back impurities and unplasticised material (Brydson, 1973).

10 Thin carry bags made of PP are carefully separated from PE and extruded into lumps. Here presence of air, moisture or even other polymer can lead to degradation and clogging of the screw channel. When there is no way for volatile matter to go out, there can be explosion given high temperature.

11 A wire mesh is attached with breaker plate to remove contaminants. There is invariably a fair amount of impurities in shredded material loaded into the extruder. In normal operation the mesh gets clogged very fast and needs replacement almost every minute. This operation is performed manually, wherein the screws of the hot barrel are opened with the help of a spanner, in all probability without switching the heating off, to change the wire mesh.

12 Bangalore in particular faces a severe shortage of power. As a consequence there is shutdown of power for 2 hours each in every morning and afternoon. In addition, industries are barred from using power from 6 P.M. to 10 P.M. This has considerable impact on production and extrusion process. Each time production is stopped due to unscheduled power shut down, the matter inside the extruder, due to long residence time, starts degrading. Particularly PVC emits Hydrogen chloride and other products of degradation when removed from the extruder once the power is restored.

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