Guidelines for Disposal of Thermoset Plastic Waste including Sheet moulding compound (SMC)/Fiber Reinforced Plastic (FRP)

CENTRAL POLLUTION CONTROL BOARD
(Ministry of Environment, Forest and Climate Change,
Government of India)
'Parivesh Bhawan' C.B.D.Cum-Office Complex,
East Arjun Nagar, Shahdara, Delhi-110032
(May, 2016)

CONTENTS

Background:

It is well known that plastic waste are non-biodegradable & remain on earth for several years. Further, some of the plastic waste like thermoset plastic waste can't be remoulded/recycled and may cause environmental issues. In view of non-recyclable nature of the thermoset plastic, the petitioner Sh. Money Goyal & Akash Seth filed a petition No OA 124/2014 in Hon'ble NGT in respect of non-recyclability of SMC/FRP enclosures being used by some Electricity Departments in Haryana, Punjab, UP etc. Hon'ble NGT while hearing the said matter on 27.01.2015 passed the following direction:-

> "***The CPCB in consultation with the MoEF shall constitute such a Committee within a period of 2 weeks from the date of receipt of the copy of the order and thereafter, we request the Committee thus constituted to study the entire aspect and give its recommendations to the CPCB expeditiously in any event within 4 weeks.***"

The copy of the Hon'ble NGTs Order is attached as **Annexure-I**. In compliance of the Order of the Hon'ble NGT, Central Pollution Control Board constituted a Committee comprising officials from MoEF & CC, BIS, CIPET, IIT Delhi and Associated Cement Company (ACC) for framing guidelines for the purpose of proper and appropriate disposal of SMC/FRP plastic waste.

2.0 Definition of Thermoset Polymer including SMC/FRP Plastic waste:

Thermoset plastic when cured by heat or other means, changes into a substantially infusible or insoluble product. The thermoset polymer is a kind of plastic, which due to its composite chemical structure can't be re-moulded/recycled. The thermoset plastic discarded after use are accumulated & landfilled. The SMC/FRP products are a kind of thermoset plastics commonly made from composites of glass fibers embedded in polyester resin, vinylester resin, epoxy resins etc.

2.1 Definition of Sheet Moulding Compound (SMC):-

Sheet moulding compound (SMC) or sheet moulding composite is a ready to mould glass-fiber reinforced polyester material primarily used in compression moulding. This is manufactured by dispersing long strands (usually >1") of chopped fiber (commonly glass fibers or carbon fibers on a bath of resin (commonly polyester resin, vinylester resin or epoxy resin). The longer fibers in SMC result in better strength properties than standard bulk moulding compound (BMC) products.

2.2 Definition of Fibre Reinforced Polymer (FRP):-

The FRP are both thermoset and thermoplastic, FRP products having thermoset base material are discussed here. FRP composite materials consist of two or more distinct physical phases, one of which, the fibrous, is dispersed in a continuous matrix phase. Composites offer the designer a combination of properties not available in traditional materials. It is possible to introduce the fibres in the polymer matrix at highly stressed regions in a certain position, direction and volume to obtain maximum efficiency from the reinforcement, and then, within the same member to reduce the reinforcement to a minimal amount at regions of low stress. Other advantages offered by the material are its lightness, resistance to corrosion, resilience, translucency and greater efficiency in construction compared to the more conventional materials.

3.0 Chemical Structure & Properties of Thermosetting Polymers:

3.1. Epoxy resins

3.1.1 The terminology 'epoxy resin' is generally applicable to both prepolymers as well as to cured resins. The former contains reactive epoxy groups whereas the cured resin may or may not contain reactive epoxy groups. While the term can be justified in the former case, the cured resins are also called epoxy resins. Epoxy resins typically contain a three membered ring with -O- atom. Different terminologies are also used to specify the group such as epoxide, oxirane and ethoxyline group, $RCHOCH_2$. Commercial epoxy resins usually contain aliphatic, cycloaliphatic, or aromatic backbones. Epoxy resins are highly reactive presumably due to the strained three membered ring structures and react with many nucleophilic and electrophilic reagents. Therefore, a wide variety of organic compounds having active hydrogen atoms can be used as curatives. These include amines (both aliphatic/aromatic and primary/secondary), phenols, carboxylic acids, thiols, anhydrides etc. The general reaction of epoxy resin with these compounds are presented below;

3.1.2 Epoxy resins possess high resistance to chemicals and corrosion, besides having moderate toughness, flexibility and excellent mechanical and electrical behaviour. Epoxy resins are also used as outstanding adhesives for different substrates. Epoxies are used in tooling, for laminates in flooring and to a small extent in moulding powders and in road surfacing. Epoxy resins are used for encapsulation of miniature components, particularly in space crafts. Epoxy resin laminates are useful in aircraft industry, while Carbon fiber/epoxy resin composites are used for structural modification in aeroplanes and epoxy/aramid fibers find uses in the design of small boats.

3.2. Unsaturated polyester resins

3.2.1 Linear unsaturated polyesters, which are often, called prepolymers have varied industrial applications. Unsaturation is introduced into the resin molecule using an unsaturated dicarboxylic acid such as maleic acid. For example, polyester of the following type is generated by reaction between ethylene glycol and maleic acid**;**

3.2.1 Commercial unsaturated polyesters are based on phthalic acid, maleic acid, ethylene glycol, and butanediol. The crosslink density, which represents the average number of crosslinks between polyester chains and the average length of the crosslinks, determines the mechanical properties of the product. The crosslink density, in turn, depends on the relative amount of the unsaturated acids used to prepare the prepolymer. The average length of the crosslinks depends on the relative amounts of the prepolymer and monomer and on the copolymerization behaviour of the two double bonds. For example, fumarate-styrene system yields a harder and tougher material than fumaratemethyl methacrylate system. The unsaturated polyester- matrix is employed in fiber-reinforced plastics (FRP) structures. The resins are also useful for decorative coatings. The resin finds use in the manufacturing of large structures such as boats and car bodies since it is curable at room temperature. The powder form of the resin is used in solution or emulsion form as binders for glass-fiber performs and for the manufacture of pre-impregnated cloths.

3.3. Phenolic resins

3.3.1 Phenolic polymers are obtained by the polymerization of phenol with formaldehyde [1]. The polycondensation reaction can be accelerated either by acids or by bases. The reaction yields resole prepolymers (resole phenolics) which are mixtures of mononuclear methylolphenols and various dinuclear and polynuclear compounds. Other products include substitution at o- and p- positions and the type of bridge between the rings (methylene versus ether). The typical ratio of formaldehyde to phenol is 1.2:1. Substituted phenols such as cresols (o-, m-, and p-), p-butylphenol, resorcinol, and bisphenolA are used for specific applications. Other aldehydes such as acetaldehyde, glyoxal, 2-furaldehyde are also used. The composition and molecular weights of the resole depend on the ratio of monomers, pH, temperature and other reaction conditions. For crosslinking temperature as high as 180^{o}C is necessary. During the curing process, methylene and ether bridges are formed between benzene rings to yield a network structure. Phenolic mouldings are hard, insoluble and heat resistant materials, since they are highly crosslinked and interlocked [2]. The type of resin and filler influence the chemical resistance of the cured material. Cresol and xylenol-based resins are inert towards NaOH attack, whereas simple phenolformaldehyde will be affected. Phenolic mouldings are resistant to acids except 50 % sulphuric acid, formic acid, and oxidizing acids, if the filler used is also resistant. The reins are stable up to 200^{o}C.

3.3.2 Phenol-formaldehyde mouldings are widely used for domestic plugs and switches. Used in electrical industry where high electrical insulation properties are not needed. It is used for making cases, knobs, handles and telephones. In automobile industry, the resins are used for making fuse-box covers, distributor heads, and in other applications where electrical insulation together with adequate heat resistance are needed. Heat resistant grade of the resins are used for saucepan handles, saucepanlid knobs, lamp housings, cooker handles, welding tongs, and electrical iron parts. Since the resin is hard and can be electroplated, it is used in the manufacture of 'golf ball' heads for typewriters etc. Bottle caps and closures are made from the resin in large quantities.

3.4. Urea-formaldehyde resin

3.4.1 It is an aminoplastic, a term generally used to represent resinous polymers formed by the interaction of amines or amides with aldehydes. The cured products form crosslinked insoluble and infusible thermoset. Compared to phenolic resins, the resins are cheaper, light in colour, and have better resistance to electrical tracking. However, it exhibits higher water absorption and poor heat resistance. The mono and dimethylol derivatives, formed during the reaction, further condense with urea to give the final resin structure.

3.4.2 There are many desirable properties for U-F moulding powders that enable to keep it in the highest application level. The wide range of colours is a reason for the widespread use of the material. U-F resins do not impart taste and odour to foodstuffs and beverages with which they come in contact. Another added advantage is their good electrical insulation properties with particularly good resistance to tracking. The resin can resist continuous heat upto a temperature of 70^{o}C. Some physical properties of urea-formaldehyde resins are presented in the **Table 1.**

3.4.3 The major application of urea-formaldehyde resin is in the field of electric and electronic applications. It's mainly used for making plugs, sockets and switches. In addition, it is used for domestic applications such as pot and panhandles and tablewares. In the sanitary sector, the resins are used as toilet seats and miscellaneous bathroom equipment. The wide colour range and freedom from taste and odour make the material a good choice for the manufacture of bottle caps and closures. However, nowadays, its consumption in this area has been reduced by the development of new thermoplastics. Buttons are made from U-F moulding powders due to its resistance to detergents and dry-cleaning solvents. Miscellaneous uses include meat trays, toys, knobs, lampshades etc. The bulk of U-F resins are used as adhesives for particleboard, plywood and furniture industries. Another application of the resin is in the manufacture of chipboard. U-F resins are also used to make foams. U-F foams are placed on airport runways to act as an arrester bed to stop aircraft that overshoot during emergency landings or abortive take-offs. Another large scale application of the resin lies in the manufacture of firelighters.

Table 1. Properties of urea-formaldehyde resins

Property	Units	α-cellulose filled	Wood flour filled	Plasticized	Translucent
Specific gravity	-	1.5-1.6	1.5-1.6	1.5-1.6	1.5-1.55
Tensile strength	10^3lbf/in	7.5-11.5	7-9.5	7-10	8-12
Impact strength	ft/bf	0.20-0.35	0.16-0.35	0.16-0.24	0.14-0.2
Cross-breaking strength	10^3lbf/in	11-17	11-16.5	13.5-15.5	13-17
Dielectric Strength	0.001 in	120-200	60-180	100-200	70-130
Volume resistivity	Ωm	10^{13}-10^{15}	10^{13}-10^{15}	10^{14}-10^{15}	-
Water absorption					
24h at 24°C	mg	50-130	40-170	50-90	50-100
30min at 100°C	mg	180-460	250-600	300-450	300-600

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3.5. Melamine-formaldehyde resin

3.5.1 Melamine-Formaldehyde (MF) can also react to give methylol derivatives of melamine. The methylol derivative with excess melamine undergoes polycondensation to give linear polymer, which forms three-dimensional network structure with further quantities of melamine monomer. The M-F resins are characterized by superior properties. 3.5.2 The mineral-filled resins are having low water absorption. The melamine resin is having better resistance to attack by aqueous solutions such as fruit juice and beverages. Good electrical properties are maintained at elevated temperatures. Better heat resistance and greater hardness are the added advantages. They have a wide colour range, besides track being and scratch resistance.

3.5.3 Mineral-filled melamine based compositions have superior electrical insulation and heat resistance to the cellulose-filled grades. The resins are used for the manufacture of decorative foils in compression moulding. The principal application of the resin is for the manufacture of tableware. A wide colour range distribution, surface hardness and stain resistance are the reasons. Cellulose-filled compositions are used at small levels for the manufacture of trays, clock cases and radio cabinets. The mineral-filled compounding are used in electrical applications and knobs and handles for kitchen utensils. M-F resins are widely employed for laminating applications owing to their high hardness, good scratch resistance, freedom from colour and heat resistance. They are also used as adhesives. Melamine-formaldehyde condensates are useful in textile industry. They are useful agents for permanent glazing, rot proofing, wool shrinkage control and, with phosphorus compounds, flame proofing. The resin can be used to prepare paper with enhanced wet-strength.

3.6. Polyimides

3.6.1 In Polyamides, the branched nature of the functional group facilitates the production of polymers. The backbone consists mainly of ring structures and hence high softening points. The polymers exhibit high thermal stability and are hence valuable for high temperature applications. Aromatic polyimides are formed by the polycondensation of dianhydrides with diamines. For example, polycondensation of pyromellitic anhydride with p,p'-diaminodiphenyl results in the synthesis of polyimides. The reaction is carried out in two steps. In the first step, the reaction is conducted with suitable solvents such as DMF at around 50^{o}C, where polymerization takes place with the formation of polyamic acid Thepolyamic acid is then casted as a film, by evaporating the solvent and baked at 300^{o}C in the atmosphere of nitrogen. Where polycondensation takes place to form the product. In the second step, the product is converted into the required shape. Polyimides, which can be either thermoplastic or thermoset, are widely used in aerospace applications.
3.6.2 Thermosetting polyimides provide easier processing and higher thermal resistance, while thermoplastic polyimides offer greater toughness. A comparison of the properties of epoxy and polyimide thermoset matrices is furnished in **Table 2.**

3.6.3 The polymer is having excellent resistance to oxidative degradation and is inactive towards most chemicals other than strong bases and high-energy radiations. The principal application of polyimides is as compressor seals in jet engines. It is used in data processing equipment such as pressure discs, sleeves, bearings, and as friction elements and as valve shafts in shut-off valves. Due to their heat resistance capacity and resistant to deformation, the polymers are used in soldering and welding equipment. However, the disadvantage of the polymer is that they may undergo hydrolysis and crack in water or steam at temperatures above 100^{o}C. For such purposes, polyetheretherketones (PEEK) are employed.

Table 2. Properties of Composite Matrices

Property	Epoxy	Polyimide
Modulus, GPa	2.8-4.2	3.2
Tensile Strength, MPa	55-130	56
Compressive strength, MPa	140	187
Density, g cm^{-3}	**1.15-1.2**	**1.43**
Thermal expansion coefficient, 10-6 ^{o}C	**45-65**	**50**

4.0 Sources/uses of SMC/FRP Plastic Waste;

The wide utilization of Thermoset Polymers including Sheet Moulding Compound (SMC)/Fibre Reinforced Plastics (FRP) is due to the combination of their mechanical and physical properties at the lowest system cost, without compromising on quality. Thermoset plastics are used in a broad range of applications, such as:

- **Automotive:** cars, trucks and other commercial and agricultural vehicles (body parts, structure and engine parts)
- **Mass transport:** trains, trams, light railways and monorail
- **Electrical & electronics:** housing, fuses, switchgear, etc.
- **Building & construction:** civil engineering and household fixtures
- **Domestic appliances:** coffee machines, toasters, irons etc.
- **Sanitary:** bathroom suites and hygienic surfaces.
- **Power utilities:** MCB boxes etc.

5.0 Management of Thermoset Polymer including SMC/FRP Waste

The use of polymer materials has simplified the modern life. At the same time, the extensive use of polymer materials in every walk of life have caused serious waste problems. The handling of increased amount of polymer waste has become a serious issue globally and is also a cause of depletion of petroleum resources which are an essential requirement of the mankind.

5.1 Collection, Segregation & Transportation

5.1.1 At present, no system exists with Municipal Bodies for collection, segregation & transportation of all kind of plastic waste including SMC/FRP/Polycarbonate plastic waste. However, as per Rule "6" of the Plastic Waste Management Rules, 2016:-

"1. Every local body shall be responsible for development and setting up of infrastructure for segregation, collection, storage, transportation, processing and disposal of the plastic waste either on its own or by engaging agencies or producers.

2. The local body shall be responsible for setting up, operationalisation and co-ordination of the waste management system and for performing the associated functions, namely:-

(a) Ensuring segregation, collection, storage, transportation, processing and disposal of plastic waste;
(b) ensuring that no damage is caused to the environment during this process;
(c) ensuring channelization of recyclable plastic waste fraction to recyclers;
(d) ensuring processing and disposal on non-recyclable fraction of plastic waste in accordance
with the guidelines issued by the Central Pollution Control Board;
(e) creating awareness among all stakeholders about their responsibilities;
(f) engaging civil societies or groups working with waste pickers; and
(g) ensuring that open burning of plastic waste does not take place.

3. The local body for setting up of system for plastic waste management shall seek assistance of producers and such system shall be set up within one year from the date of final publication of these rules in the Official Gazette of India.

4. The local body to frame bye-laws incorporating the provisions of these rules."

5.1.2 As per the Rule "9(1)" of the Plastic Waste Management Rules, 2016, The producers, within a period of six months from the date of publication of PWM Rules, 2016, shall work out modalities for waste collection system based on Extended Producers Responsibility and involving State Urban Development Departments, either individually or collectively, through their own distribution channel or through the local body concerned. In case of disposal of SMC/FRP waste etc. is carried out in cement kilns, the monitoring of air quality including dioxin/furan shall be the responsibility of producers to monitor the air quality on regular basis or as the case may be.

5.2 Management /Disposal Options:

The most deserved options are:

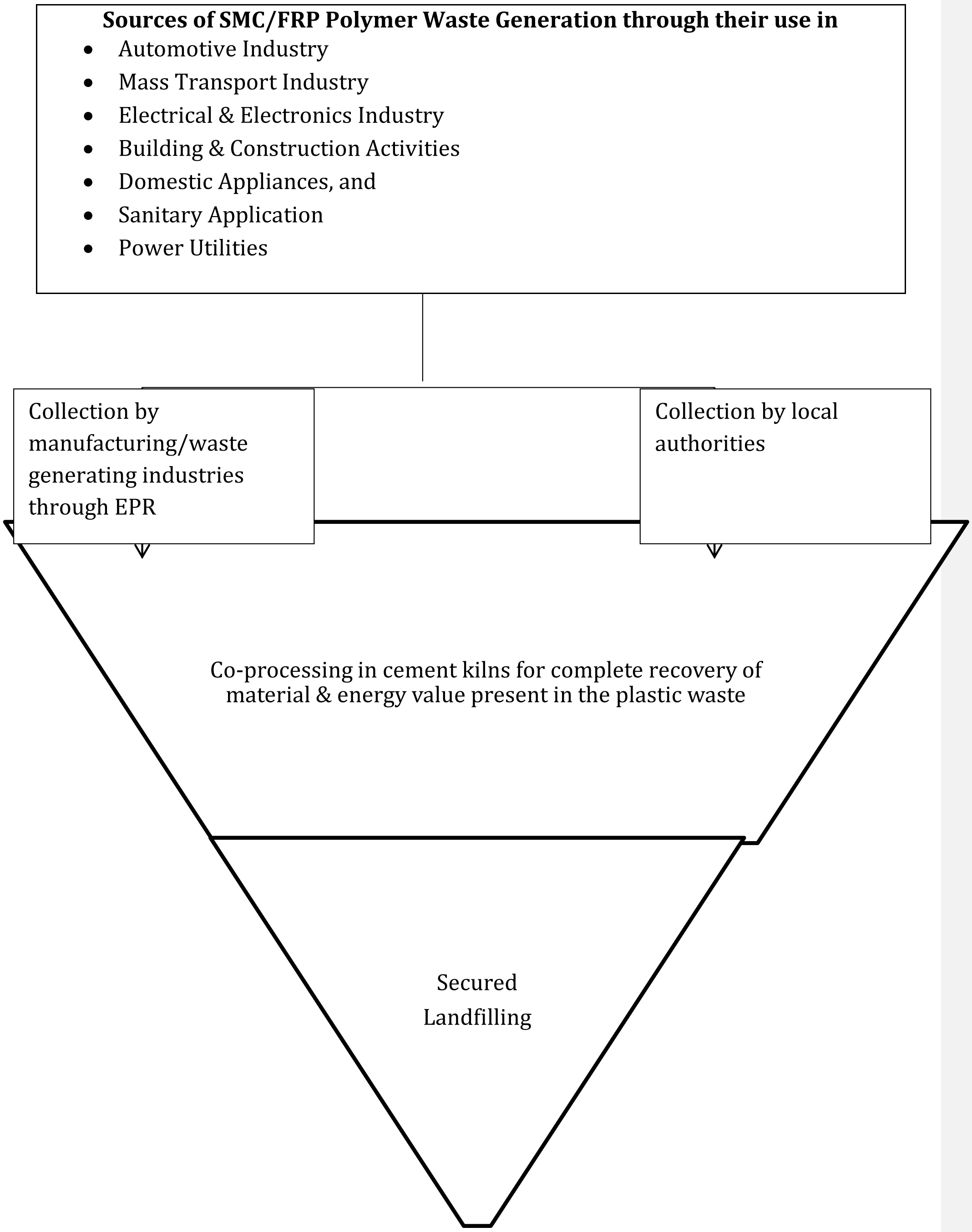
(i) Minimizing the waste generation

(ii) Co-processing in cement kilns

(iii) Disposal in secured landfills

Based on the various options practiced globally for disposal of plastic waste including SMC/FRP wastes and the waste management hierarchy, recommendation on collection & disposal of SMC/FRP wastes are illustrated in **Fig - 1:**

Figure – 1: Collection and Disposal of SMC/FRP Waste



5.2.1 Minimizing the waste generation

The most preferred option is minimization of use of SMC/FRP/Polycarbonate polymer products & promoting use of alternate material, which could be easily recyclable/reusable/degradable.

5.2.2 Co-processing of Thermosetting polymer waste in cement plants:-

Co-processing is a more environmentally friendly and sustainable method of waste disposal as compared to land filling and incineration because of reduced emissions and no residue after the treatment. Co-processing refers to the use of waste materials in industrial processes as alternative fuels or raw material (AFR) to recover energy and material from them. Due to the high temperature and long residence time in cement kiln, all types of wastes can be effectively disposed without any harmful emissions. As per the Basal Convention, variety of wastes including hazardous wastes, get disposed in an environmentally safe and sound manner through the technology of co-processing in cement kiln. Disposal of SMC / FRP wastes through co-processing is practiced in many countries as a regular method for their environmentally sound disposal. In India also, the capability of disposing FRP in an environmentally sound manner has been demonstrated through a co-processing trial carried out by ACC Limited in their Madukkarai Cement Works in Tamil Nadu. The results of this trial have demonstrated that there is no untoward impact of co-processing of FRP in the cement kiln on emissions or on the product quality. This trial was carried out at a Thermal Substitution Rate (TSR) of 0.924% which was reviewed by CPCB and permission to regularly co-process FRP waste in cement kiln at Madukkarai Cement Works granted.

5.2.2.1 Pre requisites for Co-processing of SMC/FRP polymer waste in cement plants:

Following should be considered as a prerequisite for permitting Co-processing of SMC/FRP wastes in cement plants.

a) The Producers of thermoset plastic, major user like industries, Electricity authority etc in consultation with local authority shall arrange to collect the SMC/FRP waste and handover to cement plants. They shall maintain a record of quantity generated and handed over to Cement plant.

b) The Cement plant shall maintain a record of quantity received and utilised by them.

c) The producers of SMC/FRP, major user like industries, Electricity authority etc shall assist the cement plants for establishment of required facilities for utilization of SMC/FRP like shredding, feeding system, safety measures as applicable for co-incineration, online emission monitoring for PM, SO_2 and NOx, and stack monitoring of heavy metals, dioxin and furans based on Extended Producers Responsibility.

5.2.3 Secured Landfill:

Secured landfill is another option that can be utilised for disposal of the thermoset waste. The experience has however demonstrated that the land utilised for the landfill purpose gets locked and the liability associated with this land, filled-up with materials tends to continue forever, besides the land remains unusable. Most countries have stopped the practice of utilising landfill as the option for disposal of wastes. The cost of landfill expected to keep on increasing over the time due to increase in land and fuel coils. Further, availability of land is a major issue in the cities/towns, therefore, this method could be ranked as least preferred option. The producers of thermoset plastic -SMC/FRP boxes in collaboration with power utilities may also explore the possibility of establishing common secured landfills for disposal of thermoset waste including SMC/FRP etc.

6.0 Recommendations & Conclusion:

- The most preferred option is minimization of use of SMC/FRP/Polycarbonate polymer products & promoting use of alternate material, which could be easily recyclable / reusable / degradable
- The preferred option for disposal of thermoset plastic -SMC/FRP wastes is therefore co-processing in cement plants due to its high temperature (upto2000°C and long residence time). The producers of thermoset plastic, major user like

industries, Electricity authority etc, in consultation with local authority, cement plants shall working out modalities for co-processing of such waste in cement kiln.

- The producers of SMC/FRP, major user like industries, Electricity authority etc shall assist the cement plants for establishment of required facilities for utilization of SMC/FRP like shredding, feeding system, safety measures as applicable for co-incineration, online emission monitoring for PM, SO_2 and NOx, and stack monitoring of heavy metals, dioxin and furans based on Extended Producers Responsibility.
- The State Pollution Control Board / Pollution Control Committee may consider stipulating suitable condition in consent order of the such Cement Plants on the co-processing of SMC/FRP/Polycarbonate polymer products.
- SPCB/PCC may consider incentives such as reduction of water cess / consent fee etc for such cement plants.

7.0 References

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Annexure – I

BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

Original Application No. 124/2014
And
M.A. No. 382/2014 & M.A. No. 64/2015

Money Goyal&Ors.V/s Ministry of Environment & Forests &Ors.

CORAM: HON'BLE JUSTICE DR. P. JYOTHIMANI, JUDICIAL MEMBER
HON'BLE MR. B.S. SAJWAN, EXPERT MEMBER
HON'BLE MR. RANJAN CHATTERJEE, EXPERT MEMBER

Present: Applicant / Appellant : Mr.HaminderSyal and Mr.Akash Seth, Advs.
Respondent No. 1 : Mr.VikasMalhotra, Adv.
Respondent No. 3 : Ms.ManishaAgrawalNarain, Adv. andMr. S.L. Gundli, Sr. Law Officer, CPCB
Respondent No. 4 : Mr.NitinKaushal and Mr. Rahul Meena, Advs.
Respondent Nos. 6to8 : Mr.Jayat K. Sud, SSC, PSPCL and Ms. Bonita Singh, Advs.
Respondent No. 9 : Mr.Tarunvir Singh Khehar and GurmeetKhehar, Advs.

	Date & Remarks	**Order of the Tribunal**
	Item No. 3 **January, 27 2015**	Respondent no. 3, CPCB has filed M.A. No.64/2015. The 3rd respondent has filed the above M.A seeking permission from this Tribunal to constitute an Expert group to frame guidelines on the subject matter involved.

		In the previous order of this Tribunal dated 12.12.2014 we have directed the CPCB as well as MoEF to jointly frame guidelines for the purpose of proper and appropriate disposal of SMC/FRP plastics and produce the same today. It is the case of the CPCB that since the Waste Management relating to plastic requires a thorough scientific study, the CPCB felt appropriate to constitute an expert group consisting of Members from CIPET, BIS, IIT-D and ICPE. It is their case that if such expert group studies the effects as well as the consequences of such a project it will be appropriate for the project to come in proper manner, for safe disposal of the non- recyclable and non- biodegradable plastic. The learned Counsel appearing for MoEF Mr.Malhotra, also submit that constitution of such Committee will be an appropriate step for better handling of the situation. Accordingly, taking note of the entire situation, we are of the view, that the request made on behalf of CPCB in the miscellaneous application has to be conceded. Accordingly, M.A. No. 64/2015 stand allowed and is accordingly disposed of. The CPCB in consultation with the MoEF shall constitute such a Committee within a period of 2 weeks from the date of receipt of the copy of the order and thereafter, we request the Committee thus constituted to study the entire aspect and give its recommendation to the CPCB expeditiously in any event within 4 weeks. In the meantime, the order passed in the last two paragraphs in the earlier order shall continue to be in operation. Stand over to 5th March, 2015. ……………………………………., JM (Dr. P. Jyothimani) ……………………………………., EM (B.S. Sajwan) ……………………………………., EM (RanjanChatterjee)