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THE MANAGEMENT OF AGRICULTURAL PLASTIC FILM WASTES IN ITALY

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Abstract

Plastic materials are widely used in agriculture especially for protected cultivations, for greenhouse coverings, for the construction of small tunnels, for mulching, for the seasonal covering of support structures for fruit tree crops and other numerous applications.

However, the plastic materials used for such applications tend to lose their optical and mechanical characteristics after a not too long period of time, to such an extent that they need to be replaced; this results in a huge quantity of wastes amounting to about 475,000 tons per year in the EEC countries, 100,000 tons of which only in Italy.

In the absence of precise technical regulations, these wastes are a severe risk for environment and for rural land, since they are not biodegradable and they can release noxious substances upon indiscriminately burning; in view of that, some criteria for the setting up of selective collection plans, also based on the experience in other countries, and the different possibilities of environmental friendly disposal are examined. Some of them are proposed: the use of alternative materials, like photo-bio-degradable materials or the traditional ones of better mechanical characteristics such to reduce thickness; recycling, which is a sound solution although affected by different market factors; incineration with energy recovery. At present, the last type seems to be the most interesting in Italy in that it allows to achieve a final solution to the problem of plastic waste disposal and to co-generate high amounts of electrical and thermal energy.

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1. INTRODUCTION

The use of plastic materials in agriculture was first introduced in 1948 in the U.S.A. to cover some greenhouses with cellophane and, immediately after, using PVC to cover greenhouses in Japan; it has progressively expanded over time until being widely used at present: plastic materials are now used in agriculture for packing, for irrigation and drainage pipes, as containers for the conservation and transportation of agricultural produce, for silage and, in particular, for protected cultivation.

In this sector, due to their lightness, workability and low cost, plastic materials have not only substituted other traditionally used materials, like glass for covering greenhouses or paper and straw for soil mulching, but they also have greatly contributed to give a boost to production thanks to completely new techniques, such as small tunnels, made possible by the characteristics of these innovatory materials; the greater diffusion of greenhouse cultivation and mulching techniques also produced favourable effects in reducing energy requirements for heating and water and pesticide consumption.

The use of plastic materials for protected cultivations is by now widespread all over the world, both in the industrialized and developing countries, and a further future development is envisageable in view of the great effort manufacturing industries are making in search of new materials of better and better physical characteristics and of increasingly competitive cost.

However, plastic materials used for protected cultivation are of short life duration because of the decay of their optical and mechanical characteristics due to the combined effect of exposure to U.V. rays of solar radiation and to atmospheric agents, which thus imposes to replace them after a more or less long period.

All this results in huge amounts of plastic wastes whose management is a severe environmental problem since, differently from other types of wastes, plastic wastes are not biodegradable, and if subject to uncontrolled combustion, they can release toxic substances; it is thus necessary to define the extent of the problem, to find out and analyse any possible solution, to determine the correct criteria for a sound collection and disposal system of such wastes. This problem was tackled in this paper taking Italy as a reference; our country is known to be among the countries where protected cultivation is quite widespread.

2. THE USE OF PLASTIC MATERIALS FOR PROTECTED CULTIVATIONS

Plastic materials for protected cultivations are used in the following applications:

A) Greenhouse covering

At present, greenhouses, once covered with glass, are being more and more covered by plastic materials, as an alternative to glass principally for their economic and lightness features; the selection of the plastic material type to be used generally depends on several factors, mainly the traditional use in the region, related both to the latitude and the climatic characteristics, and the protected cultivation value: for cash crops, like flowers, more expensive rigid sheets are adopted, whereas for lower value cultivations, like vegetable crops, plastic films of about 100 ÷ 200 μm thickness are often preferred.

Plastic films, the same as corrugated rigid sheets, are even used for covering semicircle-shaped tunnels or others.

The various plastic materials adopted differ in their radiometric characteristics, which cause a different greenhouse effect, in their mechanical properties and in the presence or not of additive compounds in the chemical composition which ensure the material to have thermal, anti-fog or anti-drop characteristics.

B) Small tunnels

Small tunnels consist of small support structures covered by plastic film, so as to realize a protected microclimate suitable for cultivations.

They are usually few centimetres high; during the summer season the film can be easily removed, this being a great advantage that helps the spread of these tunnels in protected cultivation.

C) Mulching

Mulching technique consists in covering the ground, where cultivations have been planted, with a material that causes a higher temperature near the root of the plants thanks to a reduced loss of heat by convection, a smaller water evaporation and the lack of weed growth.

In this kind of application plastic has replaced straw or paper, which have being used so far; today, mulching is made by plastic films, opaque or transparent, white or black, of a reduced thickness (20 ÷ 50 μm), which are mechanically laid on the ground.

Recently, the technique of mulching with transparent film has been used in hot climate Countries in order to obtain, before planting, a partial sterilization of the agricultural soil, owing to the high temperatures generated in the soil during summer by high solar radiation, which are able to eradicate the main soil-borne pathogens and to devitalize weed seeds (CPA, 1992).

D) Temporary coverings of structures for fruit trees

The technique of temporary coverings of structures for fruit trees is being increasingly used both in the Asiatic (Takakura, 1989) and European Countries; it consists in covering the structures for fruit tree specialized cultivations with plastic nets or with a 150 ÷ 200 μm thick plastic film, so that to obtain higher air temperatures, to protect the cultivation from damages caused by birds and insects as well as to limit the harmful effects due to wind, rain and hail.

In this way, larger and larger fruit trees grown areas are being protected, by virtue of advance or delay in production, which enable to sell at even higher prices; the most widespread tree cultivations practiced in Mediterranean Countries by using the above technique are vineyard, kiwi, peach-trees and apricot-trees.

E) Other applications

Other applications to protect crops by plastic materials are: floating mulch, that is mulching performed by holding the film, generally made in nonwoven fabric, above the plants; rain shelters, which are cold greenhouses with large side openings. Other versions of these applications are possible in several Countries depending on traditionally used cultivations, latitude, climate, etc.

Referring to the type of plastic material used, the most diffused among films are: Low Density Polyethylene (LDPE), Polyvinylchloride (PVC) and Ethylenvinylacetate (EVA); these materials are manufactured as one-layer sheets or, as in the case of LDPE and EVA, also as multi-layer sheets.

Moreover, for rigid sheets, bi-oriented PVC, Polycarbonate (PC), Polymethylmetacrylate (PMMA) and glass fiber reinforced Polyester (PRFV) are usually employed.

The quantities of plastic materials yearly used all over the world in the agricultural sector amount to 2 Million tons, of which about 50% for the above mentioned applications (tab. 1).

Among Nations, Italy ranks among the top plastic consumer Countries in the agricultural sector by using 250,000 tons of plastic material (tab. 2); 40% of this amount is being used for protected cultivations.

Contrary to the other applications, as irrigation pipes or containers for agricultural products, plastic materials used for plant protection have a limited life of use, also owing to their reduced thickness; their duration varies from a minimum of a season to a maximum of 2-3 years, so as the amount of consumed plastic is soon classified as waste.

Table 1. Amounts of plastic material used in agriculture in the World (from Garnaud, 1994).

	Areas (ha)	Tonnages (tons/year)
Mulching	3,500,000 - 4,000,000	550,000 - 750,000
Low structures	250,000	100,000
Greenhouses	220,000	250,000 - 350,000
Total protected cultivations		**900,000 - 1,200,000**
Irrigation piping	---	> 500,000
Micro-irrigation (drip)	1,500,000 - 2,000,000	150,000 - 200,000
Drainage	400,000	120,000 - 150,000
Silage	---	200,000
TOTAL		1,870,000 - 2,250,000

Table 2. Amounts of plastic material used in agriculture in Italy (from Pacini, 1993).

	Areas (ha)	Tonnages (tons/year)
Greenhouse films	22,300	55,000
Greenhouse rigid sheets		1,600
Low and medium tunnels	20,000	24,000
Mulching	60,000	27,000
Direct covers	---	600
Thermal screens	---	3,800
Total protected cultivations		**112,000**
Extruded netting	---	2,000
Woven netting	---	2,200
Silage	---	8,000
Irrigation piping	---	60,000
Drainage	6,000	3,000
Baler twine	---	6,000
Pots and containers	---	3,000
Disposable crates	---	8,800
Returnable crates	---	20,000
Casks for by-products	---	10,000
Trays, punnets, etc.	---	15,000
TOTAL		**250,000**

The yearly total of wastes from the agricultural sector was thus estimated (tab. 3), for Italy, to be equal to about 100,000 tons, with an incidence of about 6% on the total of plastic wastes; this percentage is slightly higher than the average of the EEC countries (equal to about 4.5%), thus proving the rather high consumption of plastic material in agriculture which makes Italy rank second in the world after Japan. From table 3 you can infer that the total production of plastic wastes in the agricultural sector was equal to 475,000 tons in 1989 in the EEC and to 532,000 tons in Western Europe, thus proving the wide diffusion of plastic material all over the European continent.

Therefore, the amounts of plastic wastes resulting from the said agricultural activities are a huge environmental problem quite hard to be solved; contrary to other types of wastes, plastic wastes are not biodegradable and cannot be burnt indiscriminately due to the risk of releasing noxious substances to the atmosphere.

Moreover, contrary to the wastes from other sectors, the agricultural plastic wastes are characterized by deposits of pesticides and plant protection products and often by organic and earthy material; on the other hand, since they are materials used by a well-defined number of specialized farms, they are usually available in restricted geographic areas and in fixed periods depending on the cropping activities, and this makes them more easily subject to a selective collection and a sound disposal plan.

Table 3. Yearly total (in tons) of post-consumption plastic wastes in the world in 1989 (from Jachia, 1992).

Country (tons/year)	**Agricultural plastic wastes**	Automotive plastic wastes	Civil works plastic wastes	Industry plastic wastes	Municipal solid plastic wastes	TOTAL PLASTIC WASTES
Belgium/Lu	**23,000**	20,000	34,000	34,000	205,000	316,000
Denmark	**10,000**	9,000	13,000	17,000	68,000	117,000
France	**72,000**	115,000	58,000	195,000	1,360,000	1,800,000
Germany	**162,000**	132,000	202,000	385,000	1,755,000	2,636,000
Greece	**6,000**	6,000	6,000	14,000	175,000	207,000
Ireland	**3,000**	4,000	4,000	5,000	63,000	79,000
Italy	**96,000**	101,000	52,000	197,000	1,155,000	1,601,000
Netherlands	**22,000**	31,000	35,000	51,000	390,000	529,000
Portugal	**4,000**	6,000	7,000	14,000	175,000	206,000
Spain	**49,000**	46,000	23,000	109,000	784,000	1,011,000
UK	**28,000**	93,000	110,000	199,000	1,400,000	1,830,000
TOTAL EEC	**475,000**	563,000	544,000	1,220,000	7,530,000	10,332,000
Austria	**16,000**	13,000	15,000	27,000	126,000	197,000
Finland	**2,000**	7,000	13,000	17,000	140,000	179,000
Norway	**14,000**	7,000	8,000	15,000	133,000	177,000
Sweden	**10,000**	17,000	21,000	29,000	205,000	282,000
Switzerland	**15,000**	13,000	15,000	23,000	200,000	266,000
TOTAL WESTERN EUROPE	**532,000**	620,000	616,000	1,331,000	8,334,000	11,433,000

3. THE DISPOSAL OF AGRICULTURAL PLASTIC FILMS

The problem of a sound disposal of agricultural plastic wastes has been scarcely considered so far by researchers, technicians and law-makers; the problem is now of such an extent to push different countries to issue technical regulations aimed at facing and solving the difficulties related to a sound choice of post-consumption plastics and to indicate preferential routes for an environmental friendly disposal of such wastes.

At present, agricultural plastic wastes in Italy are disposed by farmers in unauthorized dumping sites near cultivated areas, or in drainage channels, with severe damages to the stability of the surface and deep hydrological balance, or they are burnt in an uncontrolled way and release very hazardous pollutants to the atmosphere. Such practices are forbidden by law but a precise Regulation in this sector is still absent.

This situation, unfortunately similar also in other countries, has to be tackled by setting up adequate selective collection plans and finding out the most adequate and sound solutions of waste disposal.

3.1. Selective collection plans

The selective collection plans have to be set up following well defined design stages: the identification of the geographic area to be served, the estimate of the waste fluxes, the forecast of areas for collection and temporary storage of the waste according to the different service levels, and finally the design of the final center for the conveyance and disposal of wastes.

The area to be served depends, of course, firstly on protected cultivation surfaces and secondly on the orographic, geographic and road system characteristics of the region. The size of the geographic area within which to limit every single collection plan results, however, from a compared economic evaluation between transportation costs and benefits obtained from the re-use of plastic materials.

Waste fluxes have then to be estimated, within the defined geographic area, on the basis of the amounts and types of the plastic materials used, as well as on the basis of the periods of the year in which they are no longer needed for cropping operations and which differ according to the type of use.

Once the fluxes of materials are defined, collection and storage areas are to be foreseen and they should be organized at the farm and inter-farm levels.

Depending on the service level, these areas can be provided or not with first treatment plants (selection of different types of plastic, pressing, etc.) and they have to be located in the area to be served in such a way to optimize the transportation network also depending on the actual and potential consumption of plastic material. From these storage areas, the material is then sent to the final center where it is subject to the final treatment and disposal.

Some examples of collection plans are already in operation or under study (Scarascia et al., 1994) in some areas of Italy, on the initiative of some local Authorities, but a regulation applicable at the national level is not present yet.

In other European Countries, some examples of selective collection are already in operation; that's the case of the U.K. (Sale, 1993) where a specific Regulation, the Environmental Protection Act of 1990, imposes the manufacturing industries to take over the management of the material once it has become a waste. This has led the firms producing polyethylene for agricultural uses to organize a collection system based on the request of farmers who can dial a free-phone number once they no longer use the film: the waste is then collected, to the expense of the producing firm, in 48 hours time from the phone call and then sent to the recycling plant.

3.2. Disposal of plastic wastes

A sound disposal of agricultural plastic wastes cannot be made through sanitary landfills, unless as a temporary solution, since they are non biodegradable and tend to remain unchanged for an almost infinite time, and also because, due to their size, they can hamper the release of biogas which is spontaneously generated in the solid waste dumping site, with resulting safety problems for the management of the site itself.

The EEC strategy for waste management is aimed (Sale, 1993) at minimizing the use of non renewable resources and, secondly, at favouring the re-use and recovery or the recycling of wastes; therefore, in the case of plastic materials of agricultural origin, the possible solutions to ensure an environmental friendly waste disposal are: the use of alternative materials, recycling or incineration with energy recovery.

i) Alternative materials

As an alternative to the traditional plastic materials, researchers and the concerned industry are following two research routes: on one hand, new photo-bio-degradable materials are being tested, on the other hand, experiments are being made to improve the optical and mechanical characteristics of plastic materials and thus reduce their thickness and subsequently their mass and to increase the time of use.

As for the photo-bio-degradable materials, new polymers have been recently introduced on the European market; they are based on the principle of degradation activated by the UV component of light. The process starts after a pre-established period of use and, once it has started, it causes the destruction of the polymer since the film rapidly disintegrates into small friable fragments which can be successively ploughed in the soil since degradation also continues underground in the absence of light. The polymer degradation eventually produces water and carbon dioxide which are harmless to the soil in which they are absorbed.

The drawbacks of these materials are: the considerably higher costs with respect to the traditional ones, the need for storing them sheltered from the solar radiation before use in order to prevent earlier occurrence of degradation, and the antagonism with recycling since some components of the photo-bio-degradable plastics are a pollutant of the recycled plastic materials as they degrade at temperatures at which the latter are re-worked; therefore, due care is needed when both biodegradable and traditional plastic materials are used in the same farm in order to prevent any contamination of the latter when conveyed for recycling, if any.

On the other hand, the improvement of mechanical and optical characteristics of traditional plastic materials, makes it possible to decrease thicknesses and then the amount of wastes. As an example, figure 1 reports the stress/strain diagrams and the transmittance curves in the long I.R. of two different plastic films, a single-layer LDPE compared with an innovatory material recently introduced on the agricultural market and called TFE. These diagrams were obtained through mechanical tensile tests performed in the laboratory of material tests of the Technical-Economic Department of the University of Basilicata on a Galdabini PMA 10 press and spectrophotometric tests made in the laboratory of the Institute of Rural Buildings of the University of Bari on a Perkin-Elmer 1760 X spectrophotometer. These diagrams show that the resistances obtained from the TFE are approximately twice as much those of the LDPE, so that in the case of greenhouse covering you can use a material having half the thickness, a lower transmittance to the infra-red and thus a higher greenhouse effect than the LDPE, but TFE is still more expensive than the other plastic films.

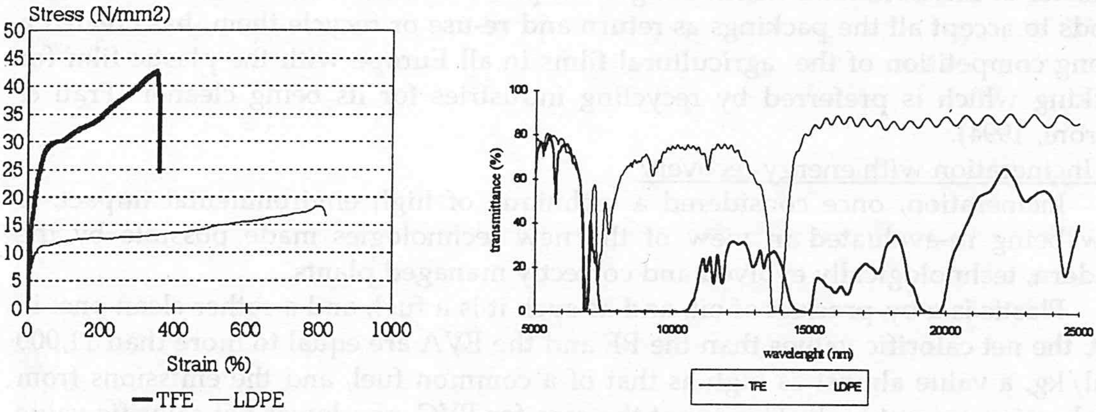

Figure 1 : Stress/strain and transmittance diagrams for a TFE film and a LDPE film

ii) Recycling

Recycling consists in producing, through adequate mechanical and thermal treatments of plastic wastes, manufactured products usable in agriculture, such as pipes for irrigation (Campos et al., 1994) or containers (pots, bags, baskets, etc.), in building, like moulds for concrete and other uses alternative to wood, in urban health and fittings, such as garbage bags and containers, benches, fences, etc. Moreover, further studies are being made on the possibility to use agricultural plastic wastes as additives for the production of "modified bitumens" for paving and water-proofing for buildings which doesn't require high investments and special pre-treatments for implementation, resulting in a final product having the same characteristics as the traditional bitumens.

The production of such manufactured products is possible only with waste material or, as in the case of recycled material for transparent mulching, with mixture of pure PE and different percentages of granules resulting from agricultural uses (Sanchez-Lopez et al., 1991).

Still, recycling can be made by mixing waste PE, after cleaning and granulation, with sawdust or rice hulls, to obtain solid fuels, or producing oil or gas by pyrolysis of waste PE (Takakura, 1989).

The recycling of plastic films of agricultural origin is a technique of low environmental impact and well appreciated by the public opinion, but some difficulties are still to be solved because of the marketing of some types of products and the high susceptibility to a number of market factors, such as: the price of crude oil which can sometimes make the new material more profitable; legislation, continuously evolving in all the countries; the influence exerted by the amounts of plastic wastes produced also in other sectors. In this connection, for instance, the law passed in Germany in 1991 by the name of its promoter, Mr. Klaus Toepfer the Minister of Environment, which obliges the producers and distributor of consumer goods to accept all the packings as return and re-use or recycle them, has created a strong competition of the agricultural films in all Europe with the plastic film for packing which is preferred by recycling industries for its being cleaner (Prati & Pieroni, 1994).

iii) Incineration with energy recovery

Incineration, once considered a technique of high environmental impact, is now being re-evaluated in view of the new technologies made possible by the modern, technologically evolved and correctly managed plants.

Plastic is a by-product of oil, and as such it is a fuel, and a rather clean one: in fact, the net calorific values than the PE and the EVA are equal to more than 11,000 kcal/kg, a value almost as high as that of a common fuel, and the emissions from combustion are not high. This is not the case for PVC, of a lower net calorific value (equal to 4,800 kcal/kg) and, in particular, capable of releasing hazardous toxic and noxious substances upon combustion, the so-called dioxins; on the other hand, this is one of the reasons which is causing a continuous decrease in the use of PVC for agricultural purposes in Europe.

Therefore, incineration is proposed in Italy as a desirable technique for the future and final solution to the problem of agricultural plastic wastes; they produce considerable amounts of energy which can be transformed into electrical power producing also a number of heat wastes which can be used in the farms located near the final disposal plant; moreover, this technique doesn't need any special treatment of the agricultural film since foreign materials, such as organic materials still attached to the film, could however participate or even favourably contribute to combustion.

The progressive tendency to choose incineration with energy recovery is proved by some early experiences which are now being made; in Spain, for instance, the plastic residues resulting from agricultural applications are used for financing energy recycling in Almeria and in Seville areas, both being characterized by a very high consumption of plastic material in the agricultural sector (Anon, 1994).

In Italy, a recent Regulation (Ministero dell'Ambiente, 1993) has established the conditions for combustion with energy recovery, direct or through gasification, for plastic residues from industrial rejects, packings and post-consumption films from selective collection with a chlorine content of less than 0.2% and having a net calorific value equal to 4,000 kcal/kg at least. This law fixes, in particular, the maximum noxious emission limits from the plants, whose nominal thermal power has to be at least equal to 3 MW and have thus to guarantee under all operational conditions a minimum combustion efficiency of 99%; this law paves the way to a sound use, for energy recovery purposes, of plastic wastes resulting from agricultural activities; that's probably the way to be followed for a profitable and environmental friendly solution.

4. CONCLUSIONS

The problems of the management of agricultural plastic film wastes, because of the extent of the phenomena, is now making people more and more conscious of the risks for environment due to the absence of precise technical regulations on the use, the post-consumption collection and disposal of these wastes.

Among the environmental friendly disposal systems, incineration with energy recovery seems to be the most appropriate and most profitable as well; on the other hand, this result is based on the fact of considering the plastic material as the intermediate use of a fuel which, before fulfilling again its original task of energy producer, has a temporary life as manufactured product.

A correct and economic solution to the problem of agricultural plastic wastes seems to have priority both for technologically advanced countries and for developing countries, in order to promote an environmental sustainable agriculture on a development policy consistent with a better quality of life should be based.

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