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Plastics - how they changed the world and posed challenges for sustainable and environmentally friendly farming. A review

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Abstract

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Plastics occupy an essential place in modern agriculture. Polymers that have long been considered substitutes for classical materials in our country are quite offensive to conquer the name of self-applicable material with a very wide range of applications. An in-depth review of the application of plastic materials in agriculture has been made. The different directions in the use of plastics, vegetables and floriculture also impose great demands on their physico-mechanical and optical properties and qualities: In agriculture, plastics are used to create and maintain specific microclimatic conditions necessary for the normal flow of the vegetation of the plants. Plastic foils play an important role in storage and irrigation systems due to their low cost, flexibility to generate interesting technical solutions, easy installation and efficiency. In addition, there is a great deal of use of plastic in vegetable/fruit transport packaging boxes, plastic pipes for soil heating, drip irrigation and rainwater installations, sliding walls to facilitate ventilation, bands to cover seeds for seedlings production, plastic fans, stopcocks, trays, pots and containers for controlled growing of flowers and vegetables etc. With the exception of the use of PVC in irrigation systems, other applications usually rely on low or high density polyethylene plastics which, depending on their use and climatic conditions, may contain organic or inorganic additives (e.g., metals) to improve the strength and stability of photo degradation, along with other properties.

The biodegradable plastic materials are a state-of-the-art scientific achievement which allows the soil to be treated after use as a result of the action of soil microorganisms. This saves labor and waste disposal costs. Although, fully biodegradable plastic materials have not yet been created. In addition, there is no evidence from toxicological studies that their use is safe for soil health, flora and fauna.

Keywords: agriculture, sustainable environment, microplastic particle, strategy

"The world is in a flux and we are in the midst of the fourth industrial revolution. Everything is changing for everyone. Europeans are facing pressing challenges such as environmental degradation and climate change, demographic transition, migration, inequality, and pressure on public finances. We are running up an ecological debt that affects everything.

Sustainable development is a complex issue, but a simple concept: it is about making sure that our economic growth allows us to maintain a model that produces fair outcomes for all of humanity; and about ensuring that humans don't consume more resources than the Earth has to offer. That means we need to modernise our economy to embrace sustainable consumption and production patterns, to correct the imbalances in our food system, and to put our mobility, the way we produce and use energy, and design our buildings onto a sustainable path.

Moving forward, we should make the circular economy the backbone of EU industrial strategy, enabling circularity in new areas and sectors, empowering consumers to make informed choices and enhancing efforts by the public sector through sustainable public procurement. The time is right, and the groundswell of public support for the EU Plastics Strategy shows there is an increasing understanding for continuing on this path.

Circular economy in action: EU putting in place the world's first comprehensive Plastics Strategy The EU Plastics Strategy41 and legislation on single-use plastics42 will protect the environment from plastic pollution while fostering growth and innovation. All plastic packaging placed on the EU market will need to be recyclable by 2030 in an economically viable manner, intentionally added microplastics and the most harmful single-use plastic items for which alternatives exist will be banned, and recycled plastics will be increasingly used to make new products "

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1. Plastics - stages of development

In 1860, Alexander Parkis discovered the plastic, and in the distant 1928 plastics were first used in vegetable-growing in England. Four years later, in the Leningrad Institute of Agrophysics, the first successful attempts with acetylcellulose canvas were made. Research in this field was expanded and deepened in the late 1930s at the Agricultutal Institute - Leningrad, and in the 1940s - at the University of Kentucky in the United States. At that time, the use of plastics in agriculture is still limited. Only in the 1950s after the discovery of high molecular weight polymers began their massive application in the field of vegetable production. In 1950, in Lesington-US, they built the first cultivation facilities with plastic coating, and only two years later, in Japan, followed by the Soviet Union, 1954 in the FRG, theGDR, in 1955, in Israel, in 1956 in England, and in 1959 in Bulgaria (Kartalov et al., 1982). The world production of plastic equipments is developing at a rapid rate of 1.5 million tons in 1950 it grew to 6.9 million tons in 1960 and 10 million tonnes in 1965 and it reached 30 million tons in 1970. At that time, polymer production doubled in 5 years. Over the last 50 years, world plastics production is about 9.1 billion with an annual growth rate of 8.7% (Geyer et al., 2017). Polymers that have long been considered substitutes for classical materials in Bulgaria re quite offensive to conquer the name of self-applicable material with a very wide range of applications. Plastics production in Bulgaria is growing at a rapid pace of 90000 tonnes in 1975. A major manufacturer in the 1980s and 1990s of a wide range of single and block greenhouses that largely satisfy the specific needs of our society for fresh and early production is the firm Polimerstroy. These facilities, which occupy more than 2400 acres in the 1990s, are resistant to snow and wind loads and are used year-round without harvest risks (Zekleev, 1983). While at this time the amount of polymers used in agriculture led by the world is Japan with more than 300,000 t per year, interesting is the example of the rapid development of this production in China. A recent study by Mormile et al. (2017) shows that plastic film consumption has increased exponentially over the last decade and Asia (70%) and Europe (16%) being primary consumers. The so-called "plasticisation era" marks a turning point in the development of agriculture, especially in horticulture (Kyrikou & Briassoulis 2007, Kasirajan and Ngouajio 2012, Mormile et al., 2017). In 2015, the annual output of plastic is about 322 million tonnes, and two percent of this production is geared to demand from agriculture and horticulture, which is a global market of $ 5.8 billion in 2012 (Plastics Europe 2015, Horton et al., 2017). The past decades of the first plastic experiments conducted at Kentucky University (US) have confirmed Dr. Emert's prognosis for their multilateral application in agriculture (Sarnel, D., 1983).

2. Requirements for agricultural materials offered in agriculture.

The different directions of use of plastics, vegetables and floriculture also impose great demands on their physical-mechanical and optical properties and qualities:

* Materials should not change their size and shape under the influence of atmospheric conditions, as their tensile strength, load, etc. are impaired. This is especially important for the roofing materials of the cultivation facilities.

* Plastic facilities must be resistant to low to -50°C and temperatures up to 100°C, to the effects of preparations, weak acids, alkalis and organic solvents.

* roofing surfaces must be hydrophilic; not to form condensation on their internal sides, and on their surface to keep dust, water and water vapor, oxygen and carbon dioxide.

* are difficult to fire.

* thermal insulation properties. Roofing materials must pass not less than 70% of the visible rays but retain up to 90% of the infrared rays emitted by plants and soil.

* light transmission. During operation, the materials must not lose more than 30% of their light transmittance and, when reinforced, more than 10%.

* Durability. An important quality of the manufactured plastic equipments is not to "aged" ie. to maintain their qualities for at least 3 to 5 years.

* Safety in use. Do not have harmful effects on humans, plants, bees. Do not attack mushrooms and bacteria.

* Easy and economical use. In the world practice and in our country there is a trend towards increasing the use of durable materials and above all of stabilized coating. The lifetime of these films, depending on the properties of stabilizing materials and production technology, is more than two years, and this is essential as the replacement of the stabilized foil stabilizes the annual consumption per hectare of greenhouse area by 400-600 kg, and the cost of covering the facilities by BGN 1080 1983;(Zekleev, 1983; Rodriquez & Pereira, 2017).

3. Types of polymeric materials used in agriculture.

In agriculture, plastics are used to create and maintain specific microclimatic conditions necessary for the normal course of plant growth. In agriculture, the following polymeric materials are found (Mitova, 2001, Kartalov, 1982, Kartalov et al., 1996, Hristov, 2011, Rodriquez & Pereira, 2017;Espi et al 2006; Hussain & Hamid, 2003)

→ Polyethylene. One of the most used polymers. It is obtained by the polymerization of ethylene. It has good optical properties. It misses 68% of the long infrared rays, 73% of the visible, 81% of the short and 80% of the long infrared rays. Compared to the glass, ultra-violet rays, the less visible, infrared shortwave and much more infrared long wavelengths, are very much missed. One of the major drawbacks is the high permeability of infrared long wavelength rays. This is due to the low thermal insulation properties. By increasing the thickness of the polyethylene film from 50 to 100 micrometers, light transmission drops by 4% without altering the quality of the transmitted light. Two to three months after use, the cloth is contaminated with dust, soot, etc. and its transparency drops by 20% and ultraviolet rays by 18%.

→ Polyvinyl chloride (PVC). It is stronger and heavier than polyethylene and can withstand temperatures from – 20^0C to + 60°C. Leaves more water vapor and less oxygen and carbon dioxide than polyethylene. Its transparency is better than that of polyethylene for visible (77%), short infrared rays (83%) and less for ultraviolet (31%) and long infrared rays (10%). The low permeability of the long infrared rays provides significantly better thermal insulation and thermal regime in the cultivation facilities. Disadvantages – Changes in dimensions due to atmospheric conditions, fragility at low temperatures and rapid pollution. The durability of the material is 18 to 24 months.

→ Armed polyvinyl chloride sheets are also available on the market. The armofol and the dunafol are produced in Bulgaria with reduced transparency and high price.

→ Polyethylene terephthalate. It is used to cover the cultivation facilities and the packaging of vegetables. There is very good light transmission. It misses 64% of ultraviolet, 87% of visible, 90% of short infrared and 66% of long infrared rays. Can be armed. Its durability is 3-4 years. However, its disadvantage is its high price.

From the polymeric coating materials listed up to now, the most widely used polyethylene fabric (90%) is less PVC (7-8%) and at least polyethylene terephthalate and rigid plastics (2-3%).

→S tabilized canvas. There is a reduced ultraviolet (25-26%) transmittance, which, unlike the unstable, is kept at baseline during use. Both abroad and the fabrics produced in Bulgaria have a shelf life of 2 years.

→ Armed polyethylene canvas. It incorporates synthetic fibers - caprin, polyamide silk, polyester filaments and others. Its use is recommended for windy areas

→ Light diffuser. It is used in countries with subtropical climates and in the southern regions of the temperate belt for shading greenhouses in the summer. Passes 30 to 50% of the light in the form of diffused and reflects 50 to 70% of it. It is produced with a thickness of 120 to 150 micrometers.

→ Photodegradable canvas. Used for mulching the soil. For 2 to 3 months it is destroyed by light and destroyed by microorganisms. It is made with a thickness of 30-50 microns.

→ Thermofixed canvas. One side is smooth and the other with pores filled with air. They reduce heat loss and thus improve the thermal regime in the greenhouse.

→ Water-soluble canvas. Used for packing of plant protection products. Dissolves simultaneously with the preparation.

→ Photoselective sails. The added dyes in their manufacture cause changes in the quantity and quality of the light penetrated. They are used for soil mulching.

→ Black canvas. It absorbs the light and heat rays and gives the soil only a small part of the heat. During the day the soil temperature is lower than under a clear canvas.

→ Gray cloth (matte). There is limited use.

→ Green canvas. It suppresses the growth of weeds as their weight decreases by 75% compared to the transparent canvas.

→ Red-brown canvas. It misses the short infrared rays and the long rays of the solar spectrum. Therefore, by heat effect, it approaches the transparent canvas, and the effect on the weeds to the black.

→ White canvas. Passes 1-2% of the rays, and the rest reflects. It does not affect soil temperature, but improves the light regime and increases the intensity of photosynthesis. Recommended for low light areas.

→ Two-color canvas. It consists of three stripes, the middle one is transparent and the outer ones are black. Plants are sown or planted in the transparent band. They have a better thermal and herbicidal effect than the one-color sails.

→ Herbicide-containing canvas. Herbicides are added to the polyethylene feedstock. When mulching, the herbicide separates and dissolves from moisture.

→ Ethylene vinyl acetate. Produced as an EVA canvas and with temperatures ranging from -60^0 to $+ 60^0$C. It does not form water drops on its inner surface, it does not dust and has good optical properties. Its durability reaches 24 to 30 months.

→ Polyamide. The polyamide fibers are used to tie and fix the plants to the wire constructions. The polyamide cloth has very good optical properties. It passes 73% of the ultraviolet rays, 90% of the visible, 88% of the short infrared and 30% of the long infrared rays. It can withstand temperatures from -200C to over 1000C. Its disadvantage is its swelling of moisture and rapid "aging" under the influence of light.

→ Glass panes. They are suitable for covering cultivation facilities. They are easy to process, can be cut, knotted and glued. Their light transmittance is good. They leak 80% of the visible, 70% of the short infrared rays and hold the long infrared rays. Compared to the glass, the ultraviolet and short infrared rays are less visible, they have a higher light transmission capacity and a lower thermal conductivity, so the heat loss in the winter is lower яand in the summer the temperature is lower and does not occur excessively rise in air temperature. Duration of use is high 10-15 years. Disadvantages include rapid pollution and high cost.

→ Polymethacrylates. They are solid, colorless panels with very good transparency. They miss 30% of ultraviolet, 80% of visible, 88% of short infrared and 20% of long infrared rays. The thermal effect is the same as the glass. They can be successfully used for 15-20 years. Their disadvantage is the high price.

4. Practical application of polymer materials in agriculture.

- Greenhouse Coatings. Polymeric foil materials have a number of valuable properties which make them an indispensable material for the construction of solar greenhouses (Kartalov et al., 1996, Stoilov, 1983). Although polymers are used in the production of greenhouse plastic films, more than 80% of world production is based on three types of polymers: low density polyethylene, ethylacetate and vinyl and polyvinyl chloride (Espi et al 2006; Petrova-Branicheva, 2013 Mormile et al., 2017). One of the limitations in the use of plastic films in greenhouses is their useful half-life, which is about 6 and 45 months depending on UV stabilizers, which are part of their chemical structure, local climatic conditions and the use of agrochemicals among other factors (Espi et al., 2006). The polymer materials with highly stabilized, reinforced, polyethylene film developed and marketed in Bulgaria have a shelf life over six times higher than the unstabilized foil (Petrova-Branicheva, 2013; Stoilov, 1983). The reinforced polystyrene film has a high tensile strength of more than 120 kg / cm^2; relative elongation over 200%; tear strength of the polyamide fiber over 50; light transmission in the visible area over 75%; operating temperature from -40°C to + 500°C; average service life 2 years. In their studies, Boteva and Cholakov, (2013), have been shown to increase the yield of early potatoes harvested under polypropylene leaf-foliage compared to the control variant. The polypropylene coating and leaf fertilization increase the dry matter content of potato tubers.
- Tunnel cultivation facilities. These facilities have the same structural and functional characteristics as the greenhouses, with the difference that their dimensions and purpose are more specific.
- Mulch. The aim of this event is to maintain soil moisture, improve its structure and fertility, reduce erosion, reduce the growth of weeds, create optimal conditions for early development and the absorption of nutrients from plants, achieve high economic results (Hussain & Hamid 2003, Kasirajan & Ngouajio 2012; Liu et al., 2014; Kader et al., 2017). About 80% of the production of plastic mulch materials is in China, with about 19,791 thousand m^2 in 2011 and a projected annual growth of 25% (Espi et al., 2006, Liu et al., 2014). Huerta Lwanga et al. (2017) showed that the plastic mulch used in Chinese agricultural soils represented 60-100% of the soil cover. In our country, the plastic mulch also grows in both production and consumer demand. In studies with medium-early tomatoes in two variants: Multivitaminated black polypropylene (SYF-42) and no mulch as control Cholakov and Ganeva, 2007, have established the effect of polypropylene mulching on soil moisture and temperature, fruit weight, day-to-day and total yields. It has been found that black polypropylene mulching in the summer months reduces soil temperature in a layer of 0-30 cm to 2-3°C and increases soil moisture to 3.2%. However, no positive effect on fruit mass and total yield was demonstrated.
- Soil soil coatings. According to FAO (Abu-Irmaileh 2003), this is a hydrothermal process that takes place in damp soil covered with plastic films and exposed to sunlight during the warmer months for 4-5 weeks. The purpose of this tech-

nique is to sterilize the soil by heating and raising the temperature and various depths to reduce or even eliminate plant pathogens that may have been accumulated during successive crop seasons (Abu-Irmaileh 2003, Mormile et al., 2017). In Bulgaria (Hristov, 2011) solar films are used for decontamination of greenhouse, greenhouse soils and nurseries.

• Biodegradable plastic materials are a state-of-the-art science that allows soil treatment after use as a result of the action of soil micro-organisms. This saves labor and waste disposal costs. Although, fully biodegradable plastic materials have not yet been created. In addition, there is no evidence from toxicological studies that their use is safe for soil health, flora and fauna.

• Other applications of polymeric materials. Plastic foils play an important role in storage and irrigation systems due to their low cost, flexibility to generate interesting technical solutions, easy installation and efficiency. In addition, there is a great deal of use of plastic in vegetable / fruit transport packaging boxes, plastic pipes for soil heating, drip irrigation and rainwater installations, sliding walls to facilitate ventilation, bands to cover seeds for seedlings production, plastic fans, stopcocks, trays, pots and containers for controlled growing of flowers and vegetables etc. (Arnaoudov et al., 2016, Darnell, 1983, Gadjalska et al., 2017, Hussain & Hamid 2003, Petrova-Branicheva, 2016). With the exception of the use of PVC in irrigation systems, other applications usually rely on low or high density polyethylene plastics which, depending on their use and climatic conditions, may contain organic or inorganic additives (e.g., metals) to improve the strength and stability of photo degradation, along with other properties.

5. Influence of plastic debris and microplastics on soil properties. Potential environmental risk

Along with all the “epochal” discoveries and acquisitions for mankind, the plastic materials “gave” the world and the so-called “White contamination” (Liu et al., 2014). The plastic film mulch, which after use is usually disposed of in the landfill, is a major source of point contamination. Often in late autumn, especially after harvesting of vegetable crops, the field is covered with pieces of polyethylene and other plastic derivatives. In parallel with all the positive aspects, the use of plastics in agriculture can cause serious damage to the environment related to:

♦ As a result of accelerated microbial activity under plastic coatings, the nutrient content may decrease sharply.
♦ Changes in biochemical cycles of nutrients
♦ Changes in C/N ratios
♦ accelerated degradation of the organic substance due to the elevated temperature under the plastics coatings
♦ Changes in soil pH through excessive mineralization
♦ Increase in greenhouse gas emissions
♦ Adverse effects on soil flora and fauna
♦ Increased soil and water repellency
♦ Changes in soil structure, density, porosity, stability of soil aggregates
♦ Release of “ingredients” of unproven or toxic origin.

In order to improve the physico-mechanical and chemical, and in some cases the aesthetic properties of the plastic materials in their production, they are added phthalates, brominated flame retardants, alkylphenols, antioxidant chemicals and metals. The release of these toxic substances in the degradation of plastics poses a serious risk to the environment.

A hazardous source of pollution from plastics is the sewage sludge from municipal wastewater treatment plants (Lambert et al. 2014, Ramos et al. 2015). Each year, up to 63,000 tonnes and 44,000 tonnes respectively are introduced into agricultural lands in Europe and North America through the application as soil improvers of sewage sludge from municipal treatment plants. microplastics (Nizzetto et al., 2016).

The application of sewage sludge to agricultural soils is a significant source of microplastics, mainly in the form of microfibers and microspheres (Zubris & Richards 2005). In recent years, plastic pollution studies have acquired a new dimension through the study of microplastic (Rillig et al., 2017). Microplastics are a heterogeneous group of particles that differ in size, density, shape and chemical composition and come from different sources. The term microplastics characterizes particles less than 5 mm in size, and some studies have also recently included plastic particles with a size <1 mm (Rillig et alq 2017, , Horton et al., 2017; Rodriguez-Seijo & Pereira, 2017).In a suitable environment, plastic waste can be decomposed by chemical, biological or biological agents, thereby reducing its size. Microplastics (MPs) are mini-plastic fragments, and the term "microplastics" was introduced by Thompson (Thompson et al., 2004). In addition, microplastics can be directly generated by the production of cosmetics or other abrasive materials. Nanoplasts (NPs) are small microplates smaller than 0.1 mm (Bouwmeester et al., 2015, Defu He et al., 2018). In terrestrial systems, microplastics can pass through sewage sludge, air transport, improper disposal of plastic waste at landfills, such as "microspheres" from personal care applications that are not covered by waste water treatment plants and/or by decomposing plastics of agricultural use (Hurley and Nizzetto, 2018). Plastic remains are common not only in soils, oceans and other water basins, but also in drinking water sources. Plastic waste and microplastics are a global problem (Shan et al, 2018). After use between 1.5 and 4.5% of the world's plastic production is released directly into the seas (Nizzetto L. et al., 2016) and the estimated amount of plastics that had fallen into marine waters by 2015 was 250 million tons (Wright & Kelly, 2017). For now, no ways have been found for plastic microparticles to be filtered or held in any way. To date, a significant number of studies have been conducted on the impact of microplasms on soil biota. We have identified microplasms in marine inhabitants, Lumbricus terrestris, Caenorhabditis elegans and Colembola species, Folsomia candida and Proisotoma minuta (Jovanovic, B., 2017, Rillig et al., 2017, Kiyama et al., 2012, Maah et al. 2017). Through the movement of soil organisms, the plastic particles move along the depth of the soil profile. The absorption of plastic particles is also described in over a hundred marine and many terrestrial birds (Romeo et al., 2015, Zhao et al., 2016). Plastics can be a sorbent for other toxic pollutants such as persistent organic pollutants (POPs) and metal contaminants (Bakir et al., 2016). Certainly, both larger plastic and nanoparticles with water and food fall into the human body. Nanoparticles can pass through the intestinal walls and reach the lymph nodes and other vital organs. There have been reports of digestive tract blockage or abrasion and mucosal irritation (Barnes et al., 2009; Rehse et al., 2016) when inhalation or swallowing of plastic particles. The phthalates contained in some plastic products (esters used as plasticizers to increase the flexibility, transparency and durability of plastics) and bisphenol A have proven anti-androgenic properties, estrogenic activity and potential endocrine disorder (Sohoni, & Sumpter, 1998). There has also been a relationship between phthalates and diseases of various allergies, asthma, endocrine diseases and breast cancer. Micro-plastics content has been reported in seafood, salt, sugar, beer and some of the results are criticized for their accuracy and possible laboratory contamination due to lack of standardized methods for assessing microplastic presence in the food industry (Lachenmeier et al., 2015).

Although most plastic particles have low lethal toxicity, given their sustainability and adaptability, they exert selective pressures on the species with consequences for phenotypic, genetic and functional biodiversity.

Conclusion

Pollution by plastic waste is one of the planet's most serious environmental problems. Research still identifies the magnitude, effects and damage of this pollution. Plastics are products with a variety of uses. They are energy efficient, comfortable and economical. Mankind will find it hard to put an end to this 300 million tonnes of annual production. Landfilling is not always the best way to get rid of it. There are two other alternative methods: recycling and incineration. These methods take advantage of some of the value of the plastic. Recycling restores the raw material, which can then be used to make new plastic products. Burning restores the chemical energy that can be used to produce steam and electricity. Ways to deal with plastic waste can be "Waste to energy" converts plastic and organic waste into gas and liquid fuel using a variety of technologies. In the "Circular Economy" model, manufacturers and designers provide packaging and materials that can easily be recycled and reused. Today more than half of the plastic packaging can not be recycled. Solutions are being sought for consumers to reduce their plastic emissions. One of these solutions is "Cora Ball", which captures up to 35% of the laundry fibers before going to the rivers and lakes.

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