Bogdan Nedić [1)]
Desimir Jovanović [2)]
Milomir Čupović [3)]

1) Faculty of Mechanical Engineering, University of Kragujevac mail: nedic@kg.ac.rs

2) Zastava oružje, Kosovska 4, Kragujevac, j.desimir@gmail.com

3) Državni univerzitet u Novom Pazaru, Vuk Karadžić 6, Novi Pazar, mimocupovic@gmail.com

POLYMERS AND HEALTH

Abstract: *Polymers application is represented in all areas of human activity and everyday life. Therefore it is important to know their impact on human health. Polymers are mostly used as wrapping materials in construction industry and also they have great application in medicine, transportation, electronics, electrical engineering, chemical industry and agriculture. So, it is very important to study and evaluate possible harmful effects on human health. This paper is an overview of widely applicable polymer materials in the food industry and their impact on human health and the environment.*
Keywords: *polymers, food industry, human healt*

1. INTRODUCTION

Today we live in a world where there are countless environmental pollutants and other toxic substances that are harmful to human health. Among them there are materials used in the food industry and they are also present in everyday use. Polymers are much of the materials witch use has steady growth thanks to low cost and functional advantages, such as term welding, optical properties, unlimited sizes and shapes, easy to print. They could be integrated into the manufacturing process where the loading, packing and closing could be done on the same production line. Currently there are over 30,000 different natural and synthetic polymers which are primarily used for taking food packaging, some of which are polyolefin, polyester, polyvinylchloride, polystyrene, polyamide, etc.. The main disadvantage of plastic materials is their variable transmission for light, gases and steam, as well as softening in high temperatures. Knowledge of kinds and possible harmful effects on human health is imperative in the choice and use of certain types of polymers. Special attention must be taken in food industry.

2. APPLICATION OF THE POLYMERS

Approximately half of all polymers that are manufactured in Europe is used for the production of packaging. 2007. Year amounted up to 18.2 million tons, which brought business worth about 54 billion euros. Figure 1 gives an overview of the use of polymers in the packaging industry in Europe [6]. In the food industry, polymers are mostly used for packaging food products. Their purpose is to keep food fresh as long as possible by creating a controlled atmosphere, and to prevent its spoilage. Polymers are used for packaging because of the easy methods of production, chemical steadiness and inertia in contact with food, easy sterilization, aesthetic appearance and low-mass [2]. Figure 2 shows the range of the plastic containers that are now in use for packaging various

products.

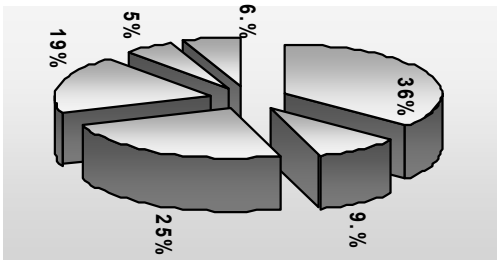

Figure 1. Use of polymers for wrapping materials

The most in use are plastomers (over 90%) such as polyetien (PE and PP), polypropylene (PP), polyvinyl chloride (PVC) and polystyrene (PS). The rest of them are duromeri, composites, elastomers and elastoplastomers (TPR).

Polyolefin's are the common term for polyethylene and polypropylene, the two most used plastic for food packaging, and other less popular olefins polymers. Very thick polyethylene is stiff, strong and tough, also resistant to chemicals and moisture, gas permeable, easy for processing and formatting. It is used for making bottles for milk, juice and water, boxes of cereals, margarine bowl, bag and store bags for trash. Slightly thick polyethylene is flexible, strong, sturdy, easy to close and resistant to moisture, is relatively transparent and generally used in cases where the term welding is necessary.

Polyviniliden chloride (PVDC) is a polymer of vyniliden chloride. It is suitable for term welding and it is an excellent barrier to water vapor, gases, and fat and oil products. It is used for inelastic packaging, as well as single-layer film, coating or part coextruded products. Major applications include packaging of chicken meat preserve meat, cheese, snacks, tea, and coffee and so on. It is also used for hot filleting, storage at low temperatures and custom packaging in the atmosphere.

Polystyrene is styrene polymer. It is hard, clean and easy to creak material, with a relatively low melting point. A common application involves packaging such as cardboard egg, dishes, eating utensils, disposable caps, cups, plates, bottles, food plate, etc..

Polyamide (also known as nylon) has mechanical and technical properties similar to FIFTH materials, so that has similar uses.

Polyesters: terefthalat Polyethylene - PET, polycarbonate - PC and polyethylene naftalat - PEN.

PET provides a good barrier to gases (oxygen and carbon dioxide) and also moisture. It is high resistant on heat, mineral oil, solutions, acids, but not at the base, therefore it is used to create packaging for many food products, particularly drinks and mineral water. The main reason for the increasing use of PET is its transparency as glass, appropriate gas barrier to maintain carbonated drinks, light weight and resistance to breakage. The main application is the packaging (bottles, jars and tubs), semi stiff foil for termoformating (plates) and oriented thin foils (bags of various kinds).

PC is clean, resistant to heat and durable, mainly used as a substitute for glass in cases such as large water bottles for reusable and small bottles that can be sterilized. Detergents based on sodium hypochlorite are not recommended to clean the PC for the catalytic activity of the appropriation biphenyl, which are a potential threat to health.

PEN has a high heat transfer ratio. Barrier properties of PEN for carbon dioxide, oxygen and water vapor are superior then PET packaging materials. Therefore PEN show better results at high temperatures, which enables multiple hot filling, washing and use. Because PEN provides protection against the transfer of flavors and odors, it is suitable for the production of bottles for drinking, such as beer.

Polyvinyl chloride (PVC) is a hard, tough, supple and medium-strong, amorphous, transparent material. It has excellent resistance to chemicals (acids and bases), fats and oils, good rheological

characteristics and stable electrical properties. Although plastic packaging is used primarily in medical and other non-food applications, its use in the food industrie includes bottles and packaging foils. PVC materials have a wide range of usage by adding phthalate, citrate and phosphate. Phthalates are mainly used for packaging non-food products such as cosmetics, toys and medical devices. Because of the possible negative impact on the health usage of phthalates in food packaging manufacturer is prohibited

Figure 2. Plastic wrapping materials for food packaging

Biopolymers - The new trend of development is the production of plastic materials that are biodegradable. There are two main groups of commercially important biodegradable polymers:

1) natural produced unmodified polymers, which are naturally liable to degradation by enzymes of microorganisms - polymers based on starch and polyhidroksialkanoat (PHA)
2) synthetically derived polymers mainly polyesters, which are liable to biodegradable - polymers based on poly (lactic acid) - PLA

Most biodegradable polymers has one common feature - a very good resistance to the water steam, in some cases even several times larger than that of conventional polymers. Foils based on starch maintain optimal humidity for fresh packaged fruits and vegetables. Biodegradable packaging is widely used in packaging for fast food and disposable cups.

3. POLYMERS IMPACT ON HEALTH

Health safety of packaging materials and packaging applications is a basic requirement for packaging food and drinks. The obligation of the manufacturer of packaging materials and packaging is certificate possession, both for raw materials and for finished product. The packaging materials users have their rights to require special control of the supplier's wrapping materials. This paper prescribed the maximum amount of harmful substances in wrapping materials and packaging, depending on the type of wrapping materials and packaging applications for certain groups of food products,

In order to improve or alter the chemical, mechanical and physical properties polymers should be added a

various additives which have a key role in creating unique polymer characteristics. There are different stabilizers, softeners, colors, antistatic, biocides, fillers, lubricants, and many others. Supplements provides strength and elasticity and protect the polymers from the influence of heat, environment and aging, and also they have a number of other useful features (antimicrobial, antistatic, act as antioxidants, absorb UV radiation, etc.). If there are additives whose chemical composition, properties and concentration are unknown, they can cause serious problems during use.

Some additives such as paint, stabilizers, softeners, etc.., contain certain heavy metals or their ions, which may pose a serious threat to health, if they migrate from a system of polymers. Most of them are toxic, so the dose should be carefully monitored in the final product. Problematic group consists of the remains of polymerization processes, such as monomers and olygomeri also can be toxic. Interaction between polymers and additives can cause creation of new, unknown chemical substances that may be dangerous to human health [1, 2].

In the space that surrounds us, there are a variety of toxic chemicals. Today there are more than 70,000 synthetic chemical, and about 1,000 new ones each year. Most of these products are marked as "harmful to human health" or "toxic", unfortunately, only a small number (7%) of them were properly tested in terms of impact on health and environmental pollution.

According to the American Organization for Safety and Health (e. Organization of Safety and Health Administration, OSHA) there is general classification of harmful chemical substances:

1) chemical substances dangerous for health, for example: Carcinogenic, irritant substances that can damage organs such as lung, skin, eyes, etc. and
2) physically dangerous chemical substances, for example flammable and explosive substances, gases under pressure, which application has risk of fire and explosion.

It is important to note that harmful chemicals can be toxic under certain conditions, and harmless in others, depending on the amount and conditions of use. In most cases important features of wrapping materials are permeability to oxygen and water steam, and the permeability of CO_2 (for carbonated drinks). There are following division of the group based on protective characteristics and permeable of the oxygen and carbon dioxide [9]:

1. ***Without barriers***: polystyrene (PS) and polyethylene (PE)
2. ***Medium barrier***: polyethylene teraftalat (PET), polyamide (PA) and polyvinyl chloride (PVC)
3. ***High barriers***: poliviniliden chloride (PVDC), ethylene-vinyl alcohol copolymer (EVOH), poliakrilonitril (PAHs), amorphous polyamide and acrylic-copolymer, etc.

It was observed that increasing of impermeability to gases, reduces other positive characteristics such as resistance to moisture, or suitability for formatting. By using several polymers in multiple thin layers, variety of features could be obtained (for example, PE classes are impermeable to water, and layers of polyvinyl alcohol (PVAL) are impermeable to oil). When using multilayer polymer structures, possibility of multiple substances migrations must be considered (migration may occur between different layers, since each layer has different accessories such as phthalates and bisfenol A, applied as softeners).

A large number of additives used to improve the shape, design and production of food wrapping materials. Therefore, law regulations of their use are often fill in. EU Directive 2002/72/EC (amendment 2004/19/EC) contains a list of the

estimated monomer and associated supplements and their specific migration limits (e. specific migration limits, SML). SML is the amount of substance in milligrams (mg) that is allowed to transfer from polymers to kilogram of food. Currently the supplement list is incomplete.

Table 1. Substance of polymer materials that may migrate into the Environment

Polymer type	MATERIALS	APPLICATION
PE-LD	Various antioxidants	Bags, various containers for storing food
PE-HD	Various antioxidants	Bags, milk bottles
PVC	Softeners(mainly phthalates), various stabilizers	Foils and plastic containers for storage of meat and sweets
PET	Acetaldehyde	Bottles for water and carbonated soft drinks, beer cans
PP	Various stabilizers, buthile hydroxyl toluene (BHT)	Bottle caps, straws for drinks
PS	Styrene (accumulate in body fat)	Glasses, cups of yogurt, various food tray

Usually polyesters as fabric softeners, based on the oily acid, are recommended for use in wrapping materials that come into contact with food, because they have low levels of migration. Soybean and linseed oil are used as softeners without migration. Paints and pigments due to the possible toxicity and excretion can be problematic [2]. In production of plastic bottles, containers and other plastic products designed for wrapping, mostly different PE materials are using (Figure 3), than follow PET and PVC (more in the EU, and less in the U.S.). The application of PET is increasing because it has several advantages (compared to PE and PVC). Most suitable for hot drinks and also can be used in microwave ovens. It has a high degree of transparency, a better balance of gas permeability and higher CO2 and oxygen impermeability. There is a new generation of PET (PET / polyethylene-nafptalat mixtures or copolymers, it has similar characteristics as glass and cans endurance as Al) [2].

Figure 3. PC bottles with bisfenol A

Figure 4. Container of PVC-U foil

Stabilizer bisfenol A (BPA) is an industrial chemical; it was first applied until the fifties, mostly used in the manufacture of polycarbonate (71%) and epoxy pitch (25%). Less is used in the manufacture of phenol pitch, unsaturated polyester pitch, pholyols / polyurethane and modified polyamides, for production of coatings (internal protective layers), metal cans and covers, coatings in containers for storing water and barrels of wine, for heat-sensitive paper, as well as production and

processing of PVC. Bisfenol A can enter in to the body oral, and / or with food and drinks in which the dismissal of the migration came from the packaging, since the polycarbonate with bisfenol A used to produce bottles for feeding infants (Fig. 3), as well as making plates, cups , container for microwave ovens and containers for storing food. In many papers (in the journal Environmental Health Perspectives, and other journals) very comprehensive comparative review of biological and toxicological impact of bisfenol A is published.

Because the human exposure to bisfenol A is below allowed daily dose, the conclusion of the European Food Safety Agency is to bisfenol is not a risk to human health at low levels, where people, including children, could be exposed during use of products that contains it. According to EU legislation, as well as in the U.S. and Japan, use of BPA is allowed in materials that come into contact with food. Influence of BPA on fertility and reproduction and the endocrine (hormonal) system is the subject of numerous debates associated with reports about the effects of small doses of BPA in rodents. But in the human body bisfenol very fast turn into a metabolite or product of metabolism without estrogenic effects and effectively excreted through the kidneys, and urine from the body. Recently, Food and Drug Administration (FDA) expressed concern about possible health effects from BPA exposure and announced that it was conducting new studies on the matter, pending possible changes in its regulatory approach.

In March 2010, the U.S. Environmental Protection Agency (EPA) released a "chemical action plan" for BPA that proposes to list BPA as a chemical of concern that may present an unreasonable risk to certain aquatic species at concentrations similar to those found in the environment, to consider rulemaking to gather additional data relevant to environmental effects, and to initiate collaborative alternatives assessment activities under its Design for the Environment (DfE) program to encourage reductions in BPA releases and exposures [5].

On the basis of results from recent studies using novel approaches to test for subtle effects, both the National Toxicology Program at the National Institutes of Health and FDA have some concern about the potential effects of BPA on the brain, behavior, and prostate gland in fetuses, infants, and young children. In cooperation with the National Toxicology Program, FDA's National Center for Toxicological Research is carrying out in-depth studies to answer key questions and clarify uncertainties about the risks of BPA [6]. In the interim:

- FDA is taking reasonable steps to reduce human exposure to BPA in the food supply. These steps include:
  - supporting the industry's actions to stop producing BPA-containing baby bottles and infant feeding cups for the U.S. market;
  - facilitating the development of alternatives to BPA for the linings of infant formula cans; and
  - supporting efforts to replace BPA or minimize BPA levels in other food can linings.
- FDA is supporting a shift to a more robust regulatory framework for oversight of BPA.
- FDA is seeking further public comment and external input on the science surrounding BPA.

Some food companies, bottle manufacturers, and paper receipt producers have voluntarily changed to BPA-free products. It is reported that some companies are exploring alternatives to BPA-containing food cans. However, others have said that for some types of

canned foods, alternatives that preserve the safety and quality of the food currently may not be available.

Politetrafluoretilen, named Teflon occupied special attention to the public as a very toxic material. It was discovered at 1938. During the production of atomic bombs. It is applied as unsticky (water and fat) thermally stable material. It can be used at temperatures between -200 and +260° C, were retains its properties. Because of its characteristics it is used as a finishing coat on the kitchen dishes (Fig. 5), various wrapping materials and furniture.

Figure 5. Dishes dragged politetrafluoretilen

Its possible harmful effects on health are reflected in the warming of temperatures over 260° C. Above this temperature there is a toxic vapor that Teflon release. Inhaling that vapor causes the so-called Teflon - flu with similar symptoms as regular flu (cough, fever and sore throat).

Environmental Protection Agency (e. Environmental Protection Agency, EPA) reported in 2005. That the perfluoro-octane acid (PFOA) used in making politetrafluoretilen is probably carcino-genic. Politetrafluoretilen was approved since 1960 from the FDA, as safe for health. International Agency for Cancer Research (e. International Agency for Research on Cancer, IARC) presents that there is insufficient evidence of carcinogenic activity politetrafluoretilen to humans and animals [2].

One of the recommendations, which can often be encountered on many web pages and refers to the dioxins that cause cancer is: Do not use plastic packaging, not to freeze water in plastic bottles and not to use plastic dishes in microwaveable. John Hophins published this on its newest papers. The reason for this recommendation is the fact that the plastic containers are releases dioxin, which is very harmful to human health. In particular, special attention must be taken on plastic containers used for heating food in a microwave oven. This especially applies to food that contains fat. It is induced that the combination of fat, high heat and plastics, releases dioxin into the food and ultimately into the cells. Instead of that, it is recommended the use of glass, such as Corning glass, pireks or ceramic, which does not contain dioxin [12].

4. CONCLUSION

Polymers are one of the most widespread materials into the environment. Polymer production industry recorded growth every year, mostly for the wrapping materials in the food industry and a slightly smaller growth in other industrial sectors. A man comes into daily contact with the polymers in various ways, mostly through food that is packed in containers, contact or breathing in the case that comes to their evaporation. Substances that are in these polymers by migration get into food, human skin and its endocrine system. On the same way they are crossing in to the land, sea, ground water, in other words in the entire ecosystem. For this reason, you need to know how these substances affect human health and the global environment. Because of their numerous, it is not always possible to perform tests and determine the possible toxicity, carcinogenic or other harmful effects. However, daily studies are necessary because this way leads to new knowledge, and answer questions. If the

polymers observed at the global level, then it is free to say that they are harmless to health and the environment. Because of that consider a number of other environmental pollutants and many other effects on human health such as stress, diet, a number of harmful ingredients in food and water (which do not originate from the polymer), bad human habits (smoking), and so on., it can be concluded that polymers has small harmful effect on health. That means that in any case we can not neglect it.

.

REFERENCES:

[1] Čatić, I., Šercer, M.: Proizvodnja polimernih tvorevina, Društvo za plastiku i gumu, Zagreb, 2004.
[2] Guneri Akovali: Plastics, Rubber and Health, Smithers Rapra Technology Limited, Shawbury, 2007.
[3] Nedić, B., Mitrović, R., Elektronski otpad, Stakleno zvono, br. 2/2009, Kragujevac
[4] Rezultati projekta TR19034: Razvoj tehnologija i tehnoloških linija za reciklažu obojenih i plemenitih metala iz elektronskog otpada, Ministarstvo za nauku i tehnološki razvoj, Mašinski fakultet, Kragujevac, 2008-2010.
[5] Linda-Jo Schierow, Sarah A. Lister, Bisphenol A (BPA) in Plastics and Possible Human Health Effects, Congressional Research Service, 2010., www.crs.gov
[6] FDA, "Bisphenol A (BPA), Update on Bisphenol A (BPA) for Use in Food: January 2010," February 19, 2010, http://www.fda.gov/NewsEvents/PublicHealthFocus/ucm064437.htm
[7] www.kemi.se,
[8] www.phthalates.com,
[9] Plastic packaging in Europe matures, www.plastemart.com
[10] www.stress.com
[11] http://www.tehnologijahrane.com/ambalaza
[12] http://kakopobeditirak.blogspot.com/2010/03/kako-se-nositi-sa-rakom-john-hopkins.htm