Irvine, CA
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SUSTAINABILITY OF KORTRAX® BARRIER RESIN (BR)

Sustainability seems to be on every company's list of things to put on a website. However, it can be very difficult to assess every possible parameter and the effect a packaging or container has on the end product's overall environmental impact or footprint. In this paper we will highlight some of the major areas where a barrier product can impact sustainability.

Parameters Assessed

Some companies do a very involved Life Cycle Analysis (LCA) and participate in any number of environmental/sustainability certification or registration firms like Ecovadis[1] or the DJSI[2] (Dow Jones Sustainability Index). In these assessments carbon or CO_2 per kilogram of product is often the quoted parameter and contaminant of concern. The LCA can also include ozone depletion, human toxicity, volatile organic carbon (VOC), ionizing radiation, acidity (acid rain as SO_2), marine and freshwater eutrophication, land use impacts on urban, agricultural, and rural, water depletion, fossil fuel depletion, and metal depletion among others. This paper will not delve into all the possible assessment tools and parameters but will touch on "the big ones" that most people talk about.

Materials of Construction

The packaging's or containers used in the industrial, pharmaceutical, health and beauty, and household products are predominantly metal (steel or tinplate), plastic (polyethylene, polypropylene, polyvinyl chloride, polyethylene terephthalate, acrylic, or polycarbonate), fiber/paper/cardboard, or glass.

Plastics are not all created equal with some being superior for solvents and permeating chemicals like a polyamide, others like polyethylene and polypropylene are better for corrosives. A permeator is a chemical that migrates through the container walls to the outside. Organic materials (mostly lower molecular weight and molecular "complexity") are especially aggressive permeators.

Kortrax® Barrier Resin (BR) polymer is a unique compound based on polyolefin and polyamide chemistry. Its major functionality is in providing a polyamide barrier to reduce or prevent solvent or active ingredient escaping the container, or reducing or eliminating the ingress of oxygen, carbon dioxide or water vapor into the product. In the following discussion, this paper will highlight metal containers versus untreated (no barrier) polyolefins, e.g., polypropylene and polyethylene, and these polyolefins with barriers added.

Steel and Tin-Plate Containers

Extreme shortages of the raw materials to make these metal containers and the price fluctuations notwithstanding, steel and tinplate have been used for over a century. Nellie Bly held the patent on the first welded steel drum in 1905. Prior to that steel, tin, aluminum, or galvanized steel drums were riveted. The welding process allowed for high production rates at lower costs and less leakage. Various linings to protect the metal and the ladings were introduced in the 1930s and 1940s.

Plastics are the relative newcomer enjoying their first century starting in the 1950s. Polyethylene was among the first successful plastics used for drums and containers.

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[1] What is EcoVadis? – EcoVadis Help Center

[2] ESG | The Report What is the Dow Jones Sustainability Index? (esgthereport.com)

Steel is touted by the manufacturers and users of steel packaging's as being infinitely recyclable and it certainly is in the broader scope. Further, it is collected and recycled at a higher rate than other competitive packaging materials.

However, steel and tinplate are heavier than plastics and have a freight disadvantage. While useful in containing aggressive solvents and products that would permeate plastics, even lined containers have a limit on corrosive materials. Linings (phenolic and epoxy-phenolic) cannot handle very low or very high pH chemicals and some organic materials will strip the lining and expose the steel—ruining both the container and the lading.

Plastics are superior for corrosive materials and are considerably lighter. Thus, they enjoy a freight advantage. Plastics are collected for reuse and recycle less than steel, but Enhanced Producer Responsibility laws (EPR) will impel producers and consumers alike to recycle.

Environmental Impact

Reviewing environmental LCA parameters for steel versus plastic, in this case using polyethylene (PE), in every single parameter monitored steel has a higher impact—footprint—than PE. Even considering that PE is ***made*** from fossil fuel, the mining, transporting, conversion and forming of steel is so energy intensive, that it is as much as four-fold higher than PE per kilogram of product. The CO_2 footprint is up to five-fold higher. Ozone depletion, freshwater eutrophication (in phosphorus equivalents), Particulate Material (PM_{10}) and other environmental variables are orders of magnitude higher for steel. Accounting for the difference in tare weight of these drums—10 kg for a heavy PE drum versus 15-20 kg for a steel drum—compounds the environmental impact from the production of steel drums because of increased carbon emissions when transported.

Steel does compensate for the environmental deficiencies by showing superior permeation control and fire resistance. Plastics cannot become as fire resistant as steel (there are available additives for static control and flame resistance) but using barriers they can approach the permeation rate of a steel container.

Barriers in Plastics

The use of barriers keeps the ladings in the container, some barriers also keep gases and water vapor out of the container. Over the years that barriers have been in use, it is estimated millions of gallons of chemicals have been kept in the container and out of the atmosphere. Moreover, gas vapor barriers are also used in polyolefin films to keep food fresh. Certainly, a sustainability is a plus for barriers.

The barriers for containers break down into three basic types: Polyamide based formulations, EVOH coextruded matrices, and Fluorination.

Fluorination

Fluorination is the exposure of the PE (or PP) to levels of fluorine gas for predetermined amounts of time to create a fluoropolymer coating on the inside and outside of the container[3],[4]. It is very effective for reducing or effectively eliminating the permeation of compounds out of the container. It does not stop ingress of oxygen, water vapor, or carbon dioxide. And Fluorination does not affect the mechanical recycling of the containers.

A study conducted by the Massachusetts Department of Environment Protection found fluoropolymers, PFAS and PFOS, were extracted from the bottle into the pesticide. Additional testing by Harvard, University of Florida, The US EPA, Commonwealth of Massachusetts, State of Maine, and others confirmed not only the presence of PFAS compounds in and on the fluorinated, aka 'treated,' plastic container surfaces, but also in the ladings. The levels found were several hundred-fold the 70 parts per trillion level for lifetime exposure in drinking water recommended by the US EPA.

[3] The kinetics and mechanisms of the direct fluorination of polyethylenes, Kharitonov, A.P., Taege, R., Freeier, G., and Piven, N. *Surface Coatings International Part B: Coatings Transactions*, **88**, 201-212, (2005)
[4] Perfluorinated Carboxylic Acids in Directly Fluorinated High-Density Polyethylene Material, Rand, A.R., Mabury, S.A. Environmental Science and Technology, 45, 8053-8059, (2011)

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Furthermore, in March 2021 the US EPA recommended that users of Fluorinated PE containers exercise due diligence and explore barrier packaging alternatives.

It needs to be noted that the above-mentioned analyses were conducted on a two-minute rinse of the fluorinated HDPE bottle with methanol or, in some studies, a two-hour soak with methanol. The EPA is conducting a longer-term exposure study to simulate what might be expected to be found in ladings that have been in fluorinated storage containers for a year. This study is due out in the first quarter of 2022.

Even more disturbing, PFAS compounds have been found in recycled HDPE from fluorinated containers which, given the assignment of key PFOS compounds to the CERCLA hazardous substance list with no de minimus exception, may make them unrecyclable and only disposable by incineration (high temperature incineration to destroy the fluoropolymer) or chemical recycling back to the starting components. Both less sustainable alternatives.

EVOH

EVOH is ethylene vinyl alcohol and has been used in multilayer containers and films from a few hundred milliliters up to 1000-liter Intermediate Bulk Containers with good permeation results. EVOH is superior in reducing ingress or permeation of water vapor (WVTR), oxygen (OTR), or other atmospheric gases into the filling goods. It is not quite as effective as fluorination or polyamide-based barriers on solvent permeation and egress of the drum or bottle.

EVOH works, simply because it is not a polyolefin and produces a layer of very low permeability. But EVOH requires multilayers to “tie” or bond the EVOH to the PE. It is not particularly recyclable with the conventional recycling technology because EVOH creates unmelted material globs in the recycled plastic pellets and the extruders. Thus, EVOH based barriers keep chemicals from entering the atmosphere but its claims to sustainability are decreased if not lost in its recycling/disposal.

Polyamides

Polyamide (PA) based barrier additives have also been around for over 20 years. They represent a “plug-and-play” scenario from a processing perspective. PA barriers provide the same effectiveness as a fluorination for permeation egress for most chemicals and is better than EVOH. Polyamides do this without the use of fluorine so there are no fluorine-based contaminants. PA provides effective OTR and WVTR performance. PA barriers can be easily introduced to extrusion blow molding and rotomolding operations with minimal adjustments for heat and mixing (PA has a slightly higher melting point that PE).

PA based barriers function by forming discontinuous layers of PA6 withing the walls of the PE container. These layers exhibit look like platelets or lamellae under a microscope. This “tortuous path” of overlapping platelets creates the physical barrier that impedes the migration of the chemicals and gas vapors in or out of the container.

Kortrax® BR is an engineered grade of PA6 designed to work withing PE or PP containers. Earlier iterations of polyamides did not have the superior formation that Kortrax® has and thus delamination and processing was more difficult. Additionally, to make the product visible to determine if it has been added or not, Kortrax® adds an FDA compliant UV brightener that glows blue under UV light. PE without Kortrax® BR will reflect the purple light. The UV brightener allows for quick identification of barrier container inventory as well as saved barrier regrind.

Recent permeation studies with varying volatile organic compounds (VOC’s) or solvents have resulted in much less than the 2% allowable weight loss by the USDOT (49 CFR). Normal permeation rate is in the 0.1% or less range for Kortrax® Baritainers®. Therefore, Kortrax® BR can demonstrate sustainability improvement by keeping contaminants like VOC’s out of the environment.

Kortrax® BR and its polyamide “cousins” do not have the same recycling issues as an EVOH. Kortrax® has been used for 15 years and to date there have been no issues reported by the recycling community. Kortrax® washes, grinds, and pelletizes like polyethylene. The washing or reprocessing will have the same energy and other LCA parameters versus steel or metal containers going through their respective recycling and reprocessing.

Illustrative of the improved sustainability impact of utilizing Kortrax® BR with HDPE, a study conducted for a leading international flavoring company demonstrated a favorable sustainability impact of a Kortrax® poly 55-gallon drum versus an equivalently sized steel drum even with a 900-mile transportation difference favoring the empty steel drum.

Summary

Kortrax® BR is an effective barrier additive for either HDPE or PP that has sustainability improvement in terms of:

1. Manufacturing LCA parameters that are from one fourth to orders of magnitude less than metal
2. Freight and transportation environmental impacts are less than metal
3. Prevents permeation of potentially toxic, flammable, or environmentally dangerous chemicals
4. Provides a permeation barrier without the generation of PFAS type chemicals—can be disposed or reused/recycled without potential PFOS CERCLA impact
5. Provides an oxygen and water vapor barrier to protect product freshness
6. No supply chain issues as seen in EVOH or metals
7. Production is conveniently located to minimize production
8. Can be recycle in conventional polyethylene recycling equipment unlike EVOH which generally needs to be burned or landfilled
9. Easily introduced into production operations with minimal scrap; regrind can be reprocessed in the same run or saved for a later start-up.

CONTACT INFORMATION

For further information and to lean more about Kortrax® Barrier Resin, please contact info@bppolymers or visit www.barrierplastics.com or call 949-633-1115.