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The widespread use of electronic products has drawn increased attention to their impact on the environment, due to the hazardous effects of PAH chemicals. Electronic waste, or e-waste, is said to be the fastest growing stream of hazardous waste in the world. Every year, over 50 million tons of electronic waste is created, and the amount of global e-waste is expected to grow by 8 percent per year.

Much of the concern regarding e-waste has to do with heavy metals, but they contain other hazardous chemicals which will pollute to create pernicious exposure problems in our environment. Polycyclic aromatic hydrocarbons (PAHs) are one such group of hazardous components, and they have been analyzed in soils from Longtangzhen in the Guangdong Province, which is a center for electronic waste (e-waste) recycling in China. In one study the sum of 16 concerning PAH's ranged in concentration from 25 to 4,300 ng/g (dry weight basis) in samples from pond sediment, vegetable and paddy fields, wastelands, dismantling sites, and they were not surprisingly the highest in former open burning sites.

Recently PAH chemicals have been found in consumer products, such as toys, sporting goods, tools, shoes, and electronics. According to the German Federal Institute for Risk Assessment (BFR), "Products for everyday use by consumers and children sometimes displayed very high PAH contents". Typically, these PAH chemicals are not added intentionally but they are present as impurities in some of the raw materials that are used in the production of the consumer products.

Polycyclic Aromatic Hydrocarbons (PAHs) are hazardous for both our human health and the environment. Many PAHs have been found to be toxic, mutagenic and/or carcinogenic. PAHs are found naturally in the environment and they have been around since the origin of the

galaxy. Whether by nature or by man, PAHs are typically created as environmental pollutants from the incomplete combustion of organic materials.

PAHs are not easily dissolved in water and they are lipophilic which means they are readily absorbed and distributed in an organism's fatty tissues. In general, the more aromatic rings in the PAH molecule, then the better it accumulates in the body, and PAH can bind to cellular proteins and DNA. It is shown in tests on animals that they can lead to mutations, create both immunosuppressants and birth defects, and in many cases cause cancer. Even worse are the potential nitrogen derivatives of PAH (NPAH), which are even more carcinogenic and mutagenic. In response to these concerns, the European Union has classified many PAHs as carcinogenic, mutagenic, and reprotoxic (CMR).

There are eight PAHs that are included in the REACH Annex XVII restricted substances list, which is classified as carcinogenic category 1B. These PAHs are restricted from use in rubber extender oils and articles supplied to the general public. Extender oils are historically derived as a product from crude oil that contain PAH chemicals, and they are used in the manufacturing of rubber articles for which one large application is automobile tires. Roughly 15-30% of the tire rubber formulation is extender oils.

Of course, tires are an important part of the transportation vehicle and globally we use a lot of them. Once the used tires have become worn and are not usable, then resourcefully most of them are recycled to be a filler in artificial turf fields and as playground flooring. It is a great resource value to have them repurposed but, the downside is that these applications have a high level of human activity which expose humans by dermal contact, inhalation, and incidental ingestion to any of their hazardous components. Between 20,000 and 40,000 tires may be used to create crumb rubber infill in one average soccer pitch, and there are over 11,000 synthetic turf athletic fields in the United States and greater than 13,000 in Europe with more being added every year. So in addition to the growing number of polymeric

consumer electronic materials, the math adds up to be a lot of exposure to humans, which has created the need for regulations around the hazardous PAH compounds in plastic and rubber.

The Product Safety Commission (AfPS) in Germany has assigned the requirements of PAH testing in the course of GS mark certification as a specification according to article 21 Product Safety Act (ProdSG) paragraph 1 number 3. There are 18 different PAH chemicals on this list (Table 1) which are not to exceed the individual limits of 0.2 to 1 mg/kg (depending on the contact category).

The International Electrotechnical Commission (IEC) is the world's leading organization that prepares and publishes International Standards for all electrical, electronic, and related technologies. The widespread use of electronic products has drawn increased attention to their impact on the environment. Due to the concern on their environmental impact and the associated effects on our health, the IEC created test series 62321 as an international standard to determine the levels of the concerned substances for daily use. Part 10 in this series is a test for measuring PAHs in polymers and electronics by gas chromatography-mass spectrometry (GC-MS). According to the IEC test method, considering the vulnerability of children, a lower limit value should be established. Therefore, the placing on the market of toys and childcare articles, containing any of the PAHs in concentrations greater than 0.5 mg/kg in their accessible plastic or rubber parts, should be prohibited.

For the development of the analytical method, the IEC used a standard solution that is a mix of several suspect PAH chemicals which are the same as those listed in AfPS GS 2014:01 (shown in Table 1). The following parameters are recommended in the IEC report:

Table 1. List of PAH components restricted in AfPS GS 2014:01

	Category 1	Category 2		Category 3	
Parameter		Toys in the scope of 2009/48/EC	Other products in the scope of ProdSG	Toys in the scope of 2009/48/EC	Other products in the scope of ProdSG
Benzo[a]pyrene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Benzo[e]pyrene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Benz[a]anthracene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Benzo[b]fluoranthene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Benzo[j]fluoranthene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Benzo[k]fluoranthene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Chrysene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Dibenz[a,h]anthracene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Benzo[g,h,i]perylene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Indeno[1,2,3-cd]pyrene, mg/kg	< 0.2	< 0.2	< 0.5	< 0.5	< 1
Acenaphthylene, acenaphthene, fluorene, phenanthrene, pyrene, anthracene, fluoranthene, mg/kg	<1 (sum)	<5 (sum)	<10 (sum)	<20 (sum)	<50 (sum)
Naphthalene, mg/kg	< 1	< 2		< 10	
Sum of 18 PAHs, mg/kg	< 1	< 5	< 10	< 20	< 50
Category 1	Materials intended to be put in the mouth, or materials of toys with intended to long-term skin contact (longer than 30 seconds)				
Category 2	Materials not covered by Category 1, with foreseeable skin contact for longer than 30 seconds (long-term skin contact) or repeated short-term skin contact				
Category 3	Materials not covered by category 1 or 2 with foreseeable skin contact up to 30 seconds (short-term skin contact)				

Typical chromatography analysis run times are 45 to 60 minutes when using test method IEC 62321-10 Ed.1.0 and the established AfPS GS 2014:01 test procedures. Now Phenomenex has developed a new proprietary selectivity to analyze and resolve critical PAH components per the IEC test method. The new Phenomenex Zebron™ ZB-PAH-EU GC column has a truly unique selectivity that not only improves the resolution of critical PAH components, but it reduces the analysis run time from 45 minutes down to 25 for more than a 44% improvement. In addition, there is a 'fast' method that produces results to under 14 minutes for over a 68% reduction with good resolution of critical pairs. The result is better efficiency and reliability in the lab.

Improving the lab's efficiency and effectiveness is an important tool to help protect our environment, and it is just one means that Phenomenex is diligently working with the testing labs, regulatory agencies, and polymer suppliers to ensure the protection of consumer's safety. For further details on Zebron™ ZB-PAH-EU and its time-saving PAH analysis please see the technical note below.

Improved-Test-Method-for-Fast-Measurement-of-PAHs-in-Electronic-ComponentsDownload

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APPLICATIONS

An Improved Test Method for Fast Measurement of Polycyclic Aromatic Hydrocarbons (PAHs) in Electronic Components by GC-MS using a Zebron™ ZB-PAH-EU GC Column

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Tim is an avid outdoorsman who loves to hike and ski. His most recent exploration is tall ship sailing in our local Pacific Ocean. Tim loves history and everything about the stars and space.

Introduction

There are many Polycyclic Aromatic Hydrocarbons (PAHs) that are hazardous for both our human health and the environment, and some even have toxic, mutagenic and/or carcinogenic properties. PAHs are organic compounds composed of carbon and hydrogen positioned in multiple aromatic rings. They are found naturally in the environment and they are also created as environmental pollutants during the incomplete combustion of organic materials. There are instances where the hazardous PAHs can be found in consumer products, such as toys, sporting goods, tools, shoes, and electronics. As a consequence, The Product Safety Commission (AfPS) in Germany has assigned the requirements of PAH testing in the course of GS mark certification as a specification according to article 21 Product Safety Act (ProdSG) paragraph 1 number 3. There are 18 different PAH chemicals on this list (**Table 1**) which are not to exceed the individual limits of 0.2 to 1 mg/kg (depending on the contact category).

The International Electrotechnical Commission (IEC) is the world's leading organization that prepares and publishes International Standards for all electrical, electronic, and related technologies. The widespread use of electronic products has drawn increased attention to their impact on the environment. Due to the concern on their environmental impact and the associated effects on our health, the IEC has created test series 62321 as an international standard to determine the levels of the concerned substances for daily use. Part 10 in this series is a test for measuring PAHs in polymers and electronics by gas chromatography-mass spectrometry (GC-MS) "DETERMINATION OF CERTAIN SUBSTANCES IN ELECTROTECHNICAL PRODUCTS – Part 10: Polycyclic aromatic hydrocarbons (PAHs) in polymers and electronics by gas chromatography-mass spectrometry (GC-MS)".

For the development of the analytical method, the IEC used a standard solution that is a mix of several suspect PAH chemicals which are the same as those listed in AfPS GS 2014:01. Typical chromatography analysis run times are 45 to 60 minutes when using test method IEC 62321-10 Ed.1.0 and the established AfPS GS 2014:01 test procedures. Phenomenex has developed a proprietary selectivity to optimize the analysis and resolution of the critical PAH components per the IEC test method.

Table 1.
List of PAH components restricted in AfPS GS 2014:01

	Category 1	Category 2		Category 3	
Parameter (mg/kg)		**Toys in the scope of 2009/48/EC**	**Other products in the scope of ProdSG**	**Toys in the scope of 2009/48/EC**	**Other products in the scope of ProdSG**
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Experimental

An improved fast GC-MS analytical method was developed using the Zebron ZB-PAH-EU GC column to improve the analytical separation and run time as compared to the IEC method. Optimal proprietary selectivity and column dimensions were utilized to get a highly efficient separation and faster throughput analysis. Additionally, a 10 meter column was used to reduce the analysis run time. The Zebron ZB-PAH-EU GC column was selected because:

- With its special uniquely designed stationary phase it offers enhanced resolution of the PAHs, preventing co-elution of interfering PAHs that can cause false positives and inaccurate results
- The columns are individually tested to provide consistent performance
- The ZB-PAH-EU GC column has great thermal stability with very low column bleed
- In this technical piece a faster run time is also evaluated with a 10 meter column as per the IEC test method

The temperature ramp was modified slightly to improve the peak efficiencies along with a reduction in the run, which was provided by the improved retention properties from the ZB-PAH-EU column.

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