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Transfer of Leachable Substances from Cross-Linked Peroxide Polyethylene (PEX-a) into Hemodialysis Water

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- FT, MB: Were involved in drafting and editing the manuscript.
- FT: Revised the manuscript prior to submission.

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Cross-linked polyethylene, commonly abbreviated PEX or XLPE, is a thermoplastic polymer, which is obtained through the polymerization of the ethylene.[1] Cross linking of polyethylene into PEX pipes results in improved properties, such as thermal, chemical and abrasion resistance, as well as a slower crack growth, accompanied with a greater toughness.[1] PEX piping is commonly used in home plumbing systems for heating, cooling, and water distribution systems.[1] Recently, polyethylene cross linked using peroxide (PEX-a) has become a viable alternative to polyvinyl chloride (PVC), or chlorinated polyvinyl chloride (C-PVC) for use as distribution systems for ultra-pure hemodialysis water.[2]

Research has shown that PEX-atubing can leach organic carbon and sorbing contaminants into water, especially when heated,[3] exposed to high PH levels,[4] chlorine-based disinfectants[4] or ultra-violet (UV) irradiation.[5] More than 158 compounds including antioxidants and their degradation products, compounds of known origins, and compounds with unknown origins were detected and identified in water which was in contact with PEX-a tubing.[6] Some examples include

Table 1

Chemical substances potentially leaching from PEX-a

Chemical group	CAS Number	Substance	Reference
Acetophenone derivatives	1378888-43-7	1-(3-Ethyl-4-(hydroxymethyl) phenyl)ethanone	7
	30773-71-8	1,1'-(Phenylene)bisethanone	7
Alcohols	110-03-2	2,5-dimethyl-2,5-hexanediol	7,8
	104-76-7	2-Ethyl-1-hexanol	8, 9
	67-56-1	Methanol	7
	111-87-5	n-Octanol	9
	75-65-0	tert-Butyl alcohol	7,11
Aldehydes	107-86-8	3-Methyl-2-butenal	7
	112-31-2	Decanal	8,9
	124-19-6	Nonanal	6,11
Alkanes	1560-93-6	2-Methyl pentadecane	12
	2882-96-4	3-Methyl pentadecane	12
	629-78-7	n-Heptadecane	12
	544-76-3	n-Hexadecane	12
	629-62-9	n-Pentadecane	12
Alkyl phenol	128-37-0	Butylatedhydroxytoluene	7,11
	20170-32-5	3-(3,5-Di-tert-butyl-4- hydroxyphenyl)propanoic acid	9
	6386-38-5	Methyl 3-(3,5-di-tert-butyl4-hydroxyphenyl)propionate	7,9,12
	–	Cyclohexa-1,4-diene-1,5- bis(tert-butyl)ethylidene	13
	1620-98-0	3,5-Di-tert-butyl-4- hydroxybenzaldehyde	9,13
	14035-33-7	3,5-Di-tert-butyl-4- hydroxyacetophenone	13
	96-76-4	2,4-Di-tert-butylphenol	10
	128-39-2	2,6-Di-tert-butylphenol	10
	121-00-6	2-tert-Butyl-4-methoxyphenol	14
	122-94-1	4-Butoxyphenol	11
	–	Phenolics	7

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Chemical group	CAS Number	Substance	Reference
Amides	–	Diazadiketo-cyclo-tetradecane	7
Aniline derivatives	101-67-7	4,4'-Dioctyldiphenylamine	12
Aromatic hydrocarbons	1014-60-4	1,3-Di-tert-butylbenzene	12
	1012-72-2	1,4-Di-tert-butylbenzene	7
	71-43-2	Benzene	7,11
	110-82-7	Cyclohexane	12
	95-47-6	o-Xylene	12
	106-44-4	p-Cresol	12
	106-42-3	p-xylene	12
	108-88-3	Toluene	9,11,12
	1330-20-7	Xylene(s)	8,11
Biolefinicsteroid	1224-94-8	Androsta-5,16-dien-3beta-ol	12
Bisphenol compounds	80-05-7	Bisphenol A	7
Epoxides	106-92-3	Oxirane, ((2-propenyloxy)methyl)-	7
Esters	103-23-1	Bis(2-ethylhexyl) hexanedioate	12
	109-21-7	Butyl butyrate	7
	540-88-5	tert-Butylacetate	9
	77-93-0	Triethyl citrate	12
	629-82-3	1-Oxtoxyoctane	9
	126-84-1	2,2-Diethoxypropane	8
Ethers	637-92-3	Ethyltert-butylether	8,12
	33021-02-2	Isopropyltert-butylether	11
	1634-04-4	Methyltert-butylether	11
Fatty acids	334-48-5	Decanoicacid	9
	143-07-7	Dodecanoicacid	9
	124-07-2	Octanoicacid	9
Halogenated hydrocarbons	598-99-2	Methyltrichloroacetate	9
	630-20-6	1,1,1,2-Tetrachloroethane	9
	79-01-6	Trichloroethylene	4
Heterocycles	15045-43-9	2,2,5,5-Tetramethyloxolane	6
	95-16-9	Benzothiazole	4
	110-86-1	Pyridine	9
	109-99-9	Tetrahydrofuran	4
Hydrocarbons	74663-85-7	Nonylcyclopropane	4
Inorganic	75-15-0	Carbon disulfide	4
Ketones	110-12-3	5-Methyl-2-hexanone	8
	108-94-1	Cyclohexanone	4
	120-92-3	Cyclopentanone	4
	–	Dicyclopentylone	4
	141-79-7	Mesityl oxide	8
Peroxides	110-05-4	Di-tert-butylperoxide	7
Phthalates	–	Butyl-2-methoxyethylphthalate	9
Quinones/quinone derivatives	106-51-4	1,4-Benzoquinone	4
	719-22-2	2,6-Di-t-butyl-p-benzoquinone	6-8
	82304-66-3	7,9-Di-tert-butyl-1- oxaspiro(4,5)deca-6,9-diene2,8-dione	4,9
Vinyl compounds	763-32-6	3-Methylbut-3-en-1-o	6
	115-11-7	Isobutylene	4,7
	115-18-4	Methylbutenol	4

CAS: Chemical Abstracts Service

phenols,[7-14] aldehydes,[7,8,11] esters,[8,9,12] alcohols,[7-9,12] ethers,[8,11,12] hydroperoxides,[10] ketones,[7,11] phtalates,[12] and organic carbon, which could potentially act as substrate for the growth of microorganisms on the pipe surface.[4] In a thesis work, Durand has found an increase in organic carbon for water exposed to PEX-a by 0.4 mg/L in the presence of chlorine based disinfectants.[4] Also, in another work, Connell *et al*, has found that the leached organic carbon from PEX-a was greater than 0.15 mg/L after 7 days at 23˚C,[12] exceeding the threshold value (0.1 mg/L>15˚C) which significantly increased the probability of coliform occurrence.[15] Table 1 report the common chemical substances leaching from PEX-a.

In hemodialysis, PEX-a tubing used as water distribution systems are raising concern about the potential for leaching chemicals into

the dialysis water, especially when heated during the thermal disinfection or exposed to chlorine-based disinfectants.[16] Patients on hemodialysis are exposed to hundreds of liters of dialysis water each week,however there are currently no guidelines regarding acceptable levels of these leachable substances in the dialysis water. The health effects of the leaching chemicals that have been evaluated toxicologically are significant, ranging from liver and kidney effects to adverse health outcomes on the reproductive, developmental, immune and nervous systems, endocrine disruption, and/or carcinogenicity.[17] To date, no studies had been conducted to ascertain the effects of PEX-a leaching on dialysis water quality. We propose that particular attention be paid to research on this field in order to ensure patient safety.

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