APPROVED PHARMACEUTICAL PRODUCTS CONTAINING CYCLODEXTRINS

The list of the cyclodextrins-containing pharmaceutical products approved and marketed has been continuously increasing (Table 2 and 3)\textsuperscript{1,2,3}.

Table 1 gives a summary of the number of active ingredients formulated with various CDs showing that most of them contain BCD or its derivative. Among the derivatives hydroxypropyl (HP), sulfobutyl ether (SBE) and random methyl (RM) cyclodextrins can be found in some formulations.

These tables do not show the two drugs where the active ingredient is a CD: Bridion (Sugammadex) and HPBCD, which are used for reversal of neuromuscular block in anesthesia and for the treatment of fatal genetic Niemann Pick Type C disease, a cholesterol metabolism disorder, respectively. The latter one has recently received an orphan drug designation.

The tables do not show either the FDA-approved cosmeceuticals, sunscreens, hydrating creams and lotions, antiage dermataceuticals etc, which contain also cyclodextrin among the ingredients.

Vitamins, various herbal compositions, phytosterols, carotenoids, unsaturated fatty acids, fish oil, etc. usually marketed as nutraceuticals have not been taken into account either although they are on the borderline between drugs and healthy foods. The nutrition supplements with steroids for body builders have not been included either.

\textit{Table 1} Number of active pharmaceutical ingredients formulated with various cyclodextrins

<table>
<thead>
<tr>
<th></th>
<th>ACD</th>
<th>BCD</th>
<th>GCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent</td>
<td>1</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>HP</td>
<td></td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>SBE</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>RM</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>Drug</td>
<td>CD</td>
<td>Trade Name</td>
<td>Dosage Form</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----</td>
<td>-------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Aceclofenac</td>
<td>BCD</td>
<td>Aceclofenac-B-Cyclodextrin</td>
<td>Tablet</td>
</tr>
<tr>
<td>Benexate</td>
<td>BCD</td>
<td>Ulgut/Lonmiel</td>
<td>Capsule</td>
</tr>
<tr>
<td>Betahistine</td>
<td>BCD</td>
<td>Betahist</td>
<td>Tablet</td>
</tr>
<tr>
<td>Cefotiam</td>
<td>BCD</td>
<td>Pansporin-T</td>
<td>Tablet</td>
</tr>
<tr>
<td>Cephalosporin (E1207)</td>
<td>BCD</td>
<td>Meiact</td>
<td>Tablet</td>
</tr>
<tr>
<td>Cetirizine</td>
<td>BCD</td>
<td>Zyrtec</td>
<td>Chewing tablet</td>
</tr>
<tr>
<td>Cisapride</td>
<td>BCD</td>
<td>Propulsid</td>
<td>Suppository</td>
</tr>
<tr>
<td>Chlor Diazepoxide</td>
<td>BCD</td>
<td>Transillium</td>
<td>Tablet</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>BCD</td>
<td>Glymesason</td>
<td>Ointment</td>
</tr>
<tr>
<td>Dextromethorphan</td>
<td>BCD</td>
<td>Ryndthisol</td>
<td>Tablet</td>
</tr>
<tr>
<td>Diphenhydramine</td>
<td>BCD</td>
<td>Stada-Travel</td>
<td>Chewing tablet</td>
</tr>
<tr>
<td>Ethinyl estradiol</td>
<td>BCD</td>
<td>Safyral/Beyaz/Lorina</td>
<td>dospirenone; ethinyl estradiol; levomefolate calcium tablet</td>
</tr>
<tr>
<td>Flunarizine</td>
<td>BCD</td>
<td>Fluner</td>
<td>Tablet</td>
</tr>
<tr>
<td>Garlic Extract</td>
<td>BCD</td>
<td></td>
<td>Various dragees</td>
</tr>
<tr>
<td>Histamine dihydrochloride</td>
<td>CD</td>
<td>Australian dream</td>
<td>Pain relieving antiarthritis cream</td>
</tr>
<tr>
<td>Iodine</td>
<td>BCD</td>
<td>Mena-Gargle</td>
<td>solution</td>
</tr>
<tr>
<td>Meloxicam</td>
<td>BCD</td>
<td>Mobit</td>
<td>Tablet, suppository</td>
</tr>
<tr>
<td>Menthol/camphor</td>
<td>BCD</td>
<td>Pain relief gel</td>
<td>Ointment</td>
</tr>
<tr>
<td>Metronidazole</td>
<td>BCD</td>
<td>Metrogel/Flagyl/Vandazol/Nidagel</td>
<td>Vaginal gel</td>
</tr>
<tr>
<td>Minoxidil</td>
<td>GCD</td>
<td>Alopexy</td>
<td>Solution</td>
</tr>
<tr>
<td>Naphasoline hydrochloride</td>
<td>CD</td>
<td>Clear eyes</td>
<td>Eye drop</td>
</tr>
<tr>
<td>Substance</td>
<td>Formulation</td>
<td>Manufacturer</td>
<td>Country</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------------------</td>
<td>--------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Nicotine</td>
<td>BCD</td>
<td>Nicorex/Nicorette</td>
<td>Tablet</td>
</tr>
<tr>
<td>Nimesulide</td>
<td>BCD</td>
<td>Nimedex</td>
<td>Tablet</td>
</tr>
<tr>
<td>Nitroglycerin</td>
<td>BCD</td>
<td>Nitropen</td>
<td>Sublingual tablet</td>
</tr>
<tr>
<td>Norfloxacin and Tinidazole</td>
<td>BCD</td>
<td>Entronor –TZ/Noroxin</td>
<td>Tablet</td>
</tr>
<tr>
<td>Omeprazol</td>
<td>BCD</td>
<td>Omebeta</td>
<td>Enteric caps.</td>
</tr>
<tr>
<td>PGE1</td>
<td>ACD</td>
<td>Prostavasin/</td>
<td>Intra-arterial inf.</td>
</tr>
<tr>
<td>PGE1</td>
<td>ACD</td>
<td>Viridal/Alprostadil/Edex/Caverject</td>
<td>Intra-cavernous inj.</td>
</tr>
<tr>
<td>PGE1</td>
<td>ACD</td>
<td>Prostavasin/</td>
<td>Intra-arterial inf.</td>
</tr>
<tr>
<td>PGE1- OP-1206</td>
<td>GCD</td>
<td>Opalmon</td>
<td>Tablet</td>
</tr>
<tr>
<td>PGE2</td>
<td>BCD</td>
<td>Prostarmon E</td>
<td>Subl. tablets</td>
</tr>
<tr>
<td>Piroxicam</td>
<td>BCD</td>
<td>Cycladol/Brexin/Flamexin</td>
<td>Tablet</td>
</tr>
<tr>
<td>Piroxicam</td>
<td>BCD</td>
<td>Cycladol/Pyrodex/Medicam</td>
<td>Tablet</td>
</tr>
<tr>
<td>Piroxicam</td>
<td>BCD</td>
<td>Brexin</td>
<td>Suppositories</td>
</tr>
<tr>
<td>Piroxicam</td>
<td>BCD</td>
<td>Flogene</td>
<td>Pediatric liquid</td>
</tr>
<tr>
<td>Refocoxib</td>
<td>BCD</td>
<td>Rofizgel</td>
<td>Tablet</td>
</tr>
<tr>
<td>Salicylic acid</td>
<td>BCD</td>
<td>Own Breakout Control</td>
<td>Antiacne Lotion</td>
</tr>
<tr>
<td>Thiomersal</td>
<td>BCD</td>
<td>Vitaseptol</td>
<td>Eye drop</td>
</tr>
<tr>
<td>Tiaprofenic acid</td>
<td>BCD</td>
<td>Surgamyl</td>
<td>Tablet</td>
</tr>
</tbody>
</table>
### Table 3: Approved pharmaceutical formulations with cyclodextrin derivatives (partial list)

<table>
<thead>
<tr>
<th>Drug</th>
<th>CD</th>
<th>Trade Name</th>
<th>Dosage form</th>
<th>Company</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisapride</td>
<td>HPBCD</td>
<td>Prepulsid</td>
<td>Suppository</td>
<td>Janssen</td>
<td>Europe</td>
</tr>
<tr>
<td>Diclofenac</td>
<td>HPBCD</td>
<td>Dyolect</td>
<td>I.v. and i.m. Solution</td>
<td>Javelin Pharm.</td>
<td>Europe</td>
</tr>
<tr>
<td>Hydrocortisone</td>
<td>HPBCD</td>
<td>Dexacort</td>
<td>Mouth wash</td>
<td>Actavis</td>
<td>Europe</td>
</tr>
<tr>
<td>Indomethacin</td>
<td>HPBCD</td>
<td>Indocid/Indocyllir</td>
<td>Eye drop</td>
<td>Chauvin/Baush &amp; Lomb</td>
<td>Europe</td>
</tr>
<tr>
<td>Itraconazole</td>
<td>HPBCD</td>
<td>Sporanox</td>
<td>Oral solution i.v. solution</td>
<td>Janssen</td>
<td>Europe/USA</td>
</tr>
<tr>
<td>Mitomycin</td>
<td>HPBCD</td>
<td>MitoExtra</td>
<td>I.v. infusion</td>
<td>Novartis</td>
<td>Europe</td>
</tr>
<tr>
<td>Televancin</td>
<td>HPBCD</td>
<td>Vibativ</td>
<td>I.v. solution</td>
<td>Astellas Pharma/Therevance</td>
<td>Europe</td>
</tr>
<tr>
<td>Perindopril tert.butylamine</td>
<td>HPBCD</td>
<td>Perindopril Erbumine</td>
<td>Tablets</td>
<td>Sandoz</td>
<td>Europe</td>
</tr>
<tr>
<td>Voriconazole</td>
<td>HPBCD</td>
<td>Vorzu</td>
<td>Tablet</td>
<td>Rhambaxy</td>
<td>India</td>
</tr>
<tr>
<td>Diclofenac</td>
<td>HPGCD</td>
<td>Voltaren/Voltarol</td>
<td>Eye drop</td>
<td>Novartis</td>
<td>Europe</td>
</tr>
<tr>
<td>Tc-99 Teoboroxime</td>
<td>HPGCD</td>
<td>CardioTec</td>
<td>I.v. solution</td>
<td>Bracco</td>
<td>USA</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>SBECED</td>
<td>Nexteron</td>
<td>I.v. solution</td>
<td>Hikma</td>
<td></td>
</tr>
<tr>
<td>Aripiprazole</td>
<td>SBECED</td>
<td>Abilify</td>
<td>I.m. solution</td>
<td>BMS/Otuska</td>
<td>USA/Europe</td>
</tr>
<tr>
<td>Maropitant</td>
<td>SBECED</td>
<td>Cerenia</td>
<td>Parenteral solution</td>
<td>Pfizer Animal Health</td>
<td>USA</td>
</tr>
<tr>
<td>Voriconazole</td>
<td>SBECED</td>
<td>Vfend</td>
<td>I.v. solution</td>
<td>Pfizer</td>
<td>USA/Europe</td>
</tr>
<tr>
<td>Ziprazidone</td>
<td>SBECED</td>
<td>Geodon, Zelnox</td>
<td>Capsule/ i.m. solution</td>
<td>Pfizer</td>
<td>USA/Europe</td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>RAMEB</td>
<td>Clorocil</td>
<td>Eye drop</td>
<td>Oftalder</td>
<td>Poland</td>
</tr>
<tr>
<td>Ostradiol</td>
<td>RAMEB</td>
<td>Aerodiol</td>
<td>Nasal spray</td>
<td>Servier</td>
<td>Europe</td>
</tr>
</tbody>
</table>

[1] [www.cyclolab.hu](http://www.cyclolab.hu)
[3] drugs.com

Éva Fenyvesi

*CycloLab R&D Laboratory Ltd., Budapest, HUNGARY*
1. CDs: Derivatives, Production, Enzymes, Toxicity

Prevalent and persistent Escherichia coli O157:H7 strains on farms are selected by bovine passage

GCD, carbohydrate utilization


Synthesis of two mono-deoxy beta-cyclodextrin derivatives as useful tools for confirming DIBAL-H promoted bis-de-O-methylation mechanism.

secondary rim regioselective bis-de-O-methylation of permethylated BCD, deoxygenation, tributyltin hydride, 2,2'-azobisisobutyronitrile, NMR

Xiao, Su Long; Zhou, De Min; Yang, Ming; Yu, Fei; Zhang, Li He; Sinay, Pierre; Zhang, Yong Min.: (2012) Chinese Chemical Letters 23(12), 1315-1318.

Beta-cyclodextrin-modified tetrahydro-beta-carboline carboxylic acid derivatives, their preparation method and medical application.

L-tryptophan, formaldehyde, 6-amino-6-deoxy-BCD, N-[(2- N-Boc-1,2,3,4- tetrahydro-beta-carboline-3)-formyl]amino acid

Li, Li ; Peng, Shiqi; Zhao, Ming; Su, Songchun.: (2012) CN102827307A, 2012/12/19/ Faming Zhanlun Shenqing, 13pp.

Study of near-symmetric cyclodextrins by compressed sensing 2D NMR.

mono(6-deoxy-6-(1,1,2,3-triazo-4-yl)-1-propane-3-O-(phenyl)) BCD, 2D HSQC-TOCSY 2D HSQC-NOESY

Misiak, Maria; Kozminski, Wiktor; Chmurski, Kazimierz; Kazimierczuk, Krzysztof.: (2013) Magnetic Resonance in Chemistry 51(2), 110-115;

Evaluation of a liquid chromatography method for quality control of methylated cyclodextrins.

Chromolith RP18 column, Halo C18 column, evaporative light scattering detector, electrospray-MS


Amphiphilic multi-arm copolymers and semiconductor nanomaterials.

21Br-BCD, t-butylacrylate, star-like poly(tert-butylacrylate-styrene) diblock copolymer

Synthesis and characterization of regioselectively monoderivatized maltooligosaccharides through a combination of tandem mass spectrometry and enzymatic hydrolysis studies.

persubstituted BCD, regioselectivity of the ring opening, ESI-MS/MS, controlled enzymic degradation, glucoamylase, LC/ESI-MS

Lesur, David; Gassama, Abdoulaye; Brique, Arnaud; Thiebault, Nicolas; Djedaini-Pilard, Florence; Pilard, Serge; Moreau, Vincent.: (2013) ARKIVOC (Gainesville, FL, United States)(2), 276-289


alpha,alpha'-dibromo-o-xylene, di-O-benzylation, intramol. etherification

Balbuena, Patricia; Goncalves-Pereira, Rita; Jimenez, Blanco, Jose L.; Garcia-Moreno, M. Isabel; Lesur, David; Ortiz, Mellet, Carmen; Garcia, Fernandez, Jose M.: (2013) Journal of Organic Chemistry 78(4), 1390-1403

Method for synthesis of beta-cyclodextrin containing twin-tailed hydrophobically associating water soluble polymer oil displacement agent.

N-allyl-N-dodecyl oleamide, alkylphenol polyoxyethylene (OP-10), 2-O-(allyloxy-2-hydroxy propyl)-BCD

Ye, Zhongbin; Gou, Guangjun; Gou, Shaohua; Liu, Zhao; Liu, Man; Jiang, Wenchao.: (2013) CN102898590A, 2013/01/30/ Faming Zhuanli Shenqing, 12pp.

A beta-cyclodextrin-containing polymeric salicylidene Schiff base: synthesis, zinc ion coordination and fluorescence resonance energy transfer with protein.

2-hydrox-5-vinylbenzaldehyde, S-1-dodecyl-S’-(alpha,alpha'-dimethyl-alpha”'-acetic acid)trithiocarbonate, mono-6-deoxy-6-aminoethyl-BCD, aggregation-induced fluorescence quenching

He, Qiangfang; Liang, Hui; Lu, Jiang.: (2013) Polymer Chemistry 4(5), 1557-1564

2. CD complexes: Preparation, Properties in solution and in solid phase, Specific guest

Novel Double Phase Transforming Organogel Based on beta- Cyclodextrin in 1,2-Propylene Glycol

reversible gel-sol transforming process, irreversible sol-gel' transforming process based on heating, smart materials

Determination of Binding Constants for Inclusion Complexes of Cyclodextrins with Organic Solvents, Ethylene Glycol, and Its Related Compounds by Means of H-1 NMR Spectroscopy

ACD, BCD, methanol, dimethyl sulfoxide, acetone,

Structure selective complexation of cyclodextrins with five polyphenols investigated by capillary electrokinetic chromatography

trans-resveratrol, astilbin, taxifolin, syringic acid

Multi-responsive supramolecular organogel with a crystalline-like structure

BCD, lithium chloride, N,N-dimethylformamide, ethylene diamine, heating-cooling process, SEM, XRD, FTIR, smart materials
Xing, Pengyao; Li, Shangyang; Xin, Feifei; Hou, Yuehui; Hao, Aiyou; Sun, Tao; Su, Jie: (2012) Carbohydrate research 367, 18-24

Design and synthesis of cholesterol-bonded fullerene and porphyrin derivatives for the preparation of a self-assembled donor-acceptor system.

interaction between CD and the cholesterol groups on porphyrin and fullerene derivs., fluorescence, SEM, self-assembled film
Wang, Ning; Jiang, Fei; Du, Zhengkun; Bao, Xichang; Wang, Ting; Yang, Renqiang.: (2012) Supramolecular Chemistry 24(11), 819-825;

High resolution interferometry as a tool for characterization of swelling of weakly charged hydrogels subjected to amphiphile and cyclodextrin exposure

acrylamide, 2-acrylamido-2-methyl-1-propanesulfonic acid, dodecyltrimethylammonium bromide, cetyltrimethylammonium bromide, CTAB/perylene, confocal laser scanning microscopy, ACD, BCD, GCD, methyl-BCD, charge density, crosslink density

Membrane insertion of sliding anchored polymers.

complexes between end-capped polyethylene glycol polymers and mono-cholesteryl CDs, Infra Red Reflection Absorption Spectroscopy, phospholipid model membranes, Brewster Angle Microscopy, AFM, neutron reflectivity
Bauer, Martin; Bernhardt, Max; Charitat, Thierry; Kekicheff, Patrick; Fajolles, Christophe; Fragneto, Giovanna; Marques, Carlos M.; Daillant, Jean.: (2013) Soft Matter 9(5), 1700-1710;

Temperature-Induced Reversible Transition between Vesicle and Supramolecular Hydrogel in the Aqueous Ionic Liquid-beta-Cyclodextrin System.

1-dodecyl-3-methylimidazolium bromide, hydrogen bonding
Redox-switchable supramolecular polymers for responsive self-healing nanofibers in water.

*ferrocene- and CD-terminated monomers, noncovalent polymers*

Yan, Qiang; Feng, Anhao; Zhang, Huijuan; Yin, Yingwu; Yuan, Jinying. (2013) Polymer Chemistry 4(4), 1216-1220

### 3. CDs in Drug Formulation

Betulin Complex in gamma-Cyclodextrin Derivatives: Properties and Antineoplastic Activities in In Vitro and In Vivo Tumor Models

*melanoma and skin cancer, octakis-[6-deoxy-6-(2-sulfanyl ethanesulfonate)]-GCD, SEM, DSC, MTT and immunocytochemistry tests, in vivo in C57BL/6J mice*


Cyclodextrin as membrane protectant in spray-drying and freeze-drying of PEGylated liposomes

*HPBCD, prednisolone disodium phosphate, reconstitution, liposomal size, size distribution, drug retention*


Photoinduced Fluorescence Activation and Nitric Oxide Release with Biocompatible Polymer Nanoparticles

*reversible switching of fluorescence, human melanoma cancer cells, cell mortality*


A Host-Guest Supramolecular Complex with Photoregulated Delivery of Nitric Oxide and Fluorescence Imaging Capacity in Cancer Cells

*rhodamine-labeled BCD conjugate, HeLa cancer cells, fluorescence microscopy, photoactivatable nanoscaled systems*


Loading antifungal drugs onto silica particles grafted with cyclodextrins by means of inclusion complex formation at the solid surface

*immobilization of antifungal drugs, limit the skin penetration, topical administration, BCDs grafted to silica, griseofulvin, coupling agent 3-amino-propylmethyldiethoxysilane, tosylated BCD, XRD, SEM*

Photoinduced fluorescence activation and nitric oxide release with biocompatible polymer nanoparticles

CD-based polymer, optical control, reversible switching of fluorescence, human melanoma cancer cells

Deniz, Erhan; Kandoth, Noufal; Fraix, Aurore; Cardile, Venera; Graziano, Adriana C.E.; Lo, Furno Debora; Gref, Ruxandra; Raymo, Francisco M.; Sortino, Salvatore: (2012) Chemistry (Weinheim an der Bergstrasse, Germany) 18(49), 15782-7

Nitric oxide scavenging rates of solubilized resveratrol and flavonoids

DIMEB, kinetic treatment, catechin, myricetin, epicatechin, epigallocatechin gallate, kaempferol, oxygen radical scavenging rates


New formulation approaches to improve solubility and drug release from fixed dose combinations: Case examples pioglitazone/ glimepiride and ezetimibe/simvastatin

HPBCD, water-soluble polyvinyl caprolactam -polyvinyl acetate- polyethylene glycol graft copolymer, ternary inclusion complex, synergistic improvement in solubility and dissolution


Effects of local simvastatin-alendronate conjugate in preventing periodontitis bone loss

simvastatin-alendronate-BCD (SIM-ALN-CD), rats, bone thickness, prophylactic SIM-ALN-CD injections


Multiresponsive Properties of Triple-Shell Architectures with Poly( N, N-diethylaminoethyl methacrylate), Poly(N-vinylcaprolactam), and Poly(N, N-dimethylaminoethyl methacrylate) as Building Blocks.

terminal-modified hyperbranched polyBCD core, multiresponsive properties

Tian, Wei; Lv, Xiaoyan; Huang, Longbiao; Ali, Nazakat; Kong, Jie.: (2012) Macromolecular Chemistry and Physics 213(23), 2450-2463;

Design and evaluation of fast dissolving film of domperidone.

solvent casting method, maltodextrin, polyvinyl alcohol, hydroxypropyl methylcellulose, inclusion complex from BCD, kneading method, IR, DSC

Solvent-free crosslinked rotaxane materials with improved settling properties, crosslinkable compositions, and their manufacture.

epsilon-caprolactam-blocked Duranol T, polyrotaxane prep. from hydroxypropyl-modified adamantaneamine-blocked polyethylene glycol-ACD polyrotaxane and epsilon-caprolactone, dibutyltin dilaurate, 2,4-bis (dodecylthiomethyl)-6-methylphenol


Betulin complex in gamma-cyclodextrin derivatives: properties and antineoplastic activities in in vitro and in vivo tumor models.

octakis-[6-deoxy-6-(2-sulfanyl ethanesulfonate)]-GCD, SEM, DSC, MTT, immunocytochem. tests

Soica, Codruta; Dehelean, Cristina; Danciu, Corina; Wang, Hai Ming ; Wenz, Gerhard ; Ambrus, Rita; Bojin, Florina; Anghel, Mariana.: (2012) International Journal of Molecular Sciences 13, 14992-15011;

Cyclodextrin-based nanospheres as drug carriers.

cross-linked Cd polymers, porous insol. nanoparticles, functionalisation for site-specific targeting

Trotta, Francesco ; Zanetti, Marco ; Cavalli, Roberta.: (2012) Beilstein Journal of Organic Chemistry 8, 2091-2099, No. 235;

2-Hydroxypropyl-beta-cyclodextrin-modified SLN of paclitaxel for overcoming p-glycoprotein function in multidrug-resistant breast cancer cells

solid lipid nanoparticles, cytotoxicity, cellular uptake, fluorescence images, verapamil


Structure and stability of warfarin-sodium inclusion complexes formed with permethylated monoamino-beta-cyclodextrin

diastereomeric host-guest inclusion complexes, CE, NMR


HP-beta-CD-PLGA nanoparticles improve the penetration and bioavailability of puerarin and enhance the therapeutic effects on brain ischemia-reperfusion injury in rats.

blood-brain barrier, poly(d,l-lactic-co-glycolic acid) nanoparticles, gelatin, infarction

Tao, Hai-quan; Meng, Qingfeng; Li, Ming-hui; Yu, Hui; Liu, Mei-fang; Du, Dan; Sun, Shou-li; Yang, Hai-cheng; Wang, Yan-ming; Ye, Wei; Yang, Li-zhuang; Zhu, Da-ling; Jiang, Chuan-lu; Peng, Hai-sheng.: (2013) Naunyn-Schmiedeberg's Archives of Pharmacology 386(1), 61-70
Multifunctional magnetic fluorescent hybrid nanoparticles as carriers for the hydrophobic anticancer drug 5-fluorouracil.

*BCD, folic acid, glutathione, magnetically guided delivery*

Sahu, Swagatika; Mohapatra, Sasmita.: (2013) Dalton Transactions 42(6), 2224-2231

Fully supramolecular vesicles as anticancer drug delivery systems.

*poly styrene backbone, hyperbranched polyglycerol, BCD, paclitaxel*

Pourjavadi, Ali; Adeli, Mohsen; Yazdi, Mojtaba.: (2013) New Journal of Chemistry 37(2), 295-298

A soft supramolecular carrier with enhanced singlet oxygen photosensitizing properties.

*zinc(ii) phthalocyanine, BCD, condensation, NMR, IR, UV/vis, fluorescence, phototherapeutic agents*

Voskuhl, Jens; Kauscher, Ulrike; Gruener, Malte; Frisch, Hendrik; Wibbeling, Birgit; Strassert, Cristian A.; Ravoo, Bart Jan.: (2013) Soft Matter 9(8), 2453-2457

Treatment of surfactants.

*pulmonary surfactant enhancement agent, cholesterol-sequestrating agent, MBCD, children with cystic fibrosis*


Virus-like particles with removable cyclodextrins enable glutathione- triggered drug release in cells.

*disulfide bonds, paclitaxel, NIH3T3 cells, cytotoxic effect*

Nii kura, Kenichi; Sugimura, Naotoshi; Musashi, Yusuke; Mikuni, Shintaro; Matsuo, Yasutaka; Kobayashi, Shintaro; Nagakawa, Keita; Takahara, Shuko; Takeuchi, Chie; Sawa, Hirofumi; Kinjo, Masataka; Ij iro, Kuniharu.: (2013) Molecular BioSystems 9(3), 501-507

4. CDs in Cell Biology

Choice of cyclodextrin for cellular cholesterol depletion for vascular endothelial cell lipid raft studies: Cell membrane alterations, cytoskeletal reorganization and cytotoxicity

*methyl-BCD, HPBCD, pulmonary artery endothelial cell, morphology alterations, cellular proteins, membrane fatty acid composition*

Hearing Loss and Hair Cell Death in Mice Given the Cholesterol-Chelating Agent Hydroxypropyl-beta-Cyclodextrin

Niemann-Pick Type C disease, peripheral auditory function, cochlear histology, long term changes to membrane composition and integrity, cell death

Crumling, Mark A.; Liu, Liqian; Thomas, Paul V.; Benson, Jennifer; Kanicki, Ariane; Kabara, Lisa; Halsey, Karin; Dolan, David; Duncan, R. Keith: (2012) PLoS one 7(12), e53280

Effect of different water-soluble forms of fullerene C60 on the metabolic activity and ultrastructure of cells in culture.

PVP, GCD, mitochondria, UV irradn., cytoprotective action, phototoxicity


Neuroprotection by cyclodextrin in cell and mouse models of Alzheimer disease.

HPBCD, cholesterol, Abeta42, improved spatial learning and memory deficits


Cholesterol organization in phosphatidylcholine liposomes: a surface plasmon resonance study.

mediated removal of cholesterol, fast pool, superlattices


cholesterol depletion of macrophages, methylated-BCD, tumor necrosis factor, ATP-binding cassette transporter

Yin, Kai; Chen, Wu-Jun; Zhou, Zhi-Gang; Zhao, Guo-Jun; Lv, Yun-Chen; Ouyang, Xin-Pin; Yu, Xiao-Hua; Fu, Yuchang; Jiang, Zhi-Sheng; Tang, Chao-Ke.: (2012) Journal of Atherosclerosis and Thrombosis 19(9), 823-836

Cellular internalization and gene silencing of siRNA polyplexes by cytocleavable cationic polyrotaxanes with tailored rigid backbones.

N,N-dimethylaminoethyl (DMAE) group-modified ACD, poly(ethylene glycol), human cervical carcinoma, gene silencing

Tamura, Atsushi; Yui, Nobuhiko.: (2013) Biomaterials 34(10), 2480-2491

MC8 Peptide-Mediated Her-2 Receptor Targeting Based on PEI-beta-CyD as Gene Delivery Vector.

polyethyleneimine, human epidermal growth factor receptor 2 (Her-2), N-succinimidyl-3-(2-pyridylthio)propionate, nanoparticles, polyplexes, Skov3 and A549 cells

Deng, Wei; Xiao, Hefang; Zeng, Xiangfu; Hu, Yiping.: (2013) Applied Biochemistry and Biotechnology 169(2), 450-461
5. CDs in Food, Cosmetics and Agrochemicals

Method for producing anticariogenic composition containing cyclodextran.

inhibiting the formation of water-insol. glucans, cyclodextran synthase, dentifrices, sweetening agents, foods, beverages


Quantitative analysis of pheromone-binding protein specificity.

Drosophila odorant-binding protein, 11-cis vaccenyl acetate, fluorescence, BCD, silk moth pheromone bombykol


Inclusion of the insecticide fenitrothion in dimethylated-beta-cyclodextrin: unusual guest disorder in the solid state and efficient retardation of the hydrolysis rate of the complexed guest in alkaline solution.

organophosphorus insecticide, DIMEB, XRD, kinetic studies


6. CDs for other Industrial Applications

Synthesis of graphene oxide decorated with magnetic cyclodextrin for fast chromium removal

wastewater, adsorption kinetic, Langmuir isotherm


Preparation and characterization of poly-carboxymethyl-beta- cyclodextrin superplasticizer

ring-opening polymerization of epoxy chloropropane and CM-beta-CD, FTIR, NMR, GPC, adsorption properties, zeta-potential, cement particles, concrete engineering

Evaluation of 14 Organic Solvents and Carriers for Screening Applications in Zebrafish Embryos and Larvae


Variation of the Viologen Electron Relay in Cyclodextrin-Based Self-Assembled Systems for Photoinduced Hydrogen Evolution from Water


An intelligent anticorrosion coating based on pH-responsive supramolecular nanocontainers


Acetylated and methylated beta-cyclodextrins as viable soluble supports for the synthesis of short 2'-oligo(deoxy)ribonucleotides in solution.

Molina, Alejandro Gimenez; Kungurtsev, Vyacheslav; Virta, Pasi; Lonnberg, Harri.: (2012) Molecules 17, 12102-12120;

Beta-cyclodextrin-mediated acetic acid catalyzed diastereoselective Mannich reaction in water.

Sukumari, Subbiah; Azath, Ismail Abulkalam; Pitchumani, Kasi.: (2012) Synlett 23(16), 2328-2332;

Fabrication of beta-cyclodextrin conjugated magnetic HNT/iron oxide composite for high-efficient decontamination of U(VI).

Yang, Shitong; Zong, Pengfei; Hu, Jun; Sheng, Guodong; Wang, Qi; Wang, Xiangke.: (2013) Chemical Engineering Journal (Amsterdam, Netherlands) 214), 376-385

Preparation and characterization of anti-fouling beta-cyclodextrin/polyester thin film nanofiltration composite membrane.

Wu, Huiqing; Tang, Beibei; Wu, Peiyi.: (2013) Journal of Membrane Science 428, 301-308
Rust inhibitor, its ingredients and application for cold-rolled steel in cold rolling process.

*monoethanolamine benzoate, triethanolamine, octadecylamine, BCD, 1,2,4-triazole, 1-hydroxy benzotriazole, morpholine benzoate, phytic acid*

Chen, Yiqing; Xu, Xiaolian; Xiao, Yu; Zhong, Bin; Ai, Fangfang; Li, Lin; Gao, Peng.: (2013) CN102899669A, 2013/01/30/ Faming Zhuanli Shenqing, 5pp.

Biodegradable lubricant and preparation method thereof.

*CD stearate, polyol, long-chain fatty acid, inorg. nanoparticles, aviation, metal processing, textile and leather fields*

Li, Dongshuang; Yang, Fada; Huang, Changshou; Fu, Dongju; Wu, Weiwei; Tan, Manlin; Yuan, Kaijie; Chen, Jianjun; Yue, Fengshu; Yang, Jian.: (2013) CN102911770A, 2013/02/06/ Faming Zhuanli Shenqing, 8pp.


*p-tert-butyl-25,27-dihydroxyl-26,28-di(ethoxy carbonyl methoxyl) calix[4]arene, mono-6-ethylenediamino-6-deoxy-BCD, Freundlich adsorption isotherm*

Zhang, Xiaomei; Shi, Liang; Xu, Guocai; Chen, Chaoyue.: (2013) Journal of Inclusion Phenomena and Macrocyclic Chemistry 75(1-2), 147-153

### 7. CDs in Sensing and Analysis

The use of methyl-beta-cyclodextrin to solubilize cholesterol prior to coating onto a C18 stationary phase

*reversed-phase mobile phases, coating levels of cholesterol, selectivity*


A novel enzyme-immobilized flow cell used as end-column chemiluminescent detection interface in open-tubular capillary electrochromatography

*hiolated BCD-modified gold nanoparticles-coated OTCEC column*


Beta-cyclodextrin decorated nanostructured SERS substrates facilitate selective detection of endocrine disruptor chemicals

*monolayer of silica nanospheres, silver, gold, mono-6-deoxy-6-((2-mercaptoethyl)amino)-BCD, 3-amino-2-naphthoic acid, potassium hydrogen phthalate, beta-estradiol*

Fang, Cheng ; Bandaru, Narasimha Murthy ; Ellis, Amanda Vera ; Voelcker, Nicolas Hans: (2012) Biosensors & bioelectronics 42, 632-639
The effects of diffusion on an exonuclease/nanopore-based DNA sequencing engine.

protein ion channel, computer simulations, lifetime

Reiner, Joseph E.; Balijepalli, Arvind; Robertson, Joseph W. F.; Drown, Bryon S.; Burden, Daniel L.; Kasianowicz, John J.: (2012) Journal of Chemical Physics 137(21), 214903/1-214903/7;

Influence of Spacer Length between Actuator and Sensor on Their Mutual Communications in Poly(N-Isopropylacrylamide-co-beta- Cyclodextrin), an Autonomous Coordinative Shrinking/Swelling Polymer.

8-anilino-1-naphthalenesulfonic acid, pNIPAM main chain

Ohashi, Hidenori; Abe, Tomoaki; Tamaki, Takanori; Yamaguchi, Takeo.: (2012) Macromolecules (Washington, DC, United States) 45(24), 9742-9750;

Determination of trace Cu, Co, Cr and Pb by X-ray fluorescence analysis with adsorption of beta-cyclodextrin polymer including PAN resin.

flake for XRF detn. without elution, filtration

Tang, Hong-mei; Qiu, Hai-ou; Tian, Yu-he; Zheng, Hong-tao; Tang, Zhi-yong.: (2012) Fenxi Shiyanshi 31(10), 89-91

Enantiomer separation with ice as a functional material-chiral ice chromatography.

ice particles, hydrogen bond formation between the polar groups in a solute mol. and the OH dangling bonds on the ice surfaces, chiral selector

Okada, Tetsuo.: (2012) Kobunshi 61(10), 783-784

A novel enzyme-immobilized flow cell used as end-column chemiluminescent detection interface in open-tubular capillary electrochromatography.

thiolated BCD-modified gold nanoparticles-coated OTCEC column

Xie, Haoyue; Wang, Zuorong; Kong, Weijun; Wang, Lin; Fu, Zhifeng.: (2013) Analyst (Cambridge, United Kingdom) 138(4), 1107-1113

Beta-cyclodextrin decorated nanostructured SERS substrates facilitate selective detection of endocrine disruptor chemicals.

river water, surface enhanced Raman scattering, silica nanospheres, mono-6-deoxy-6-((2-mercaptoethyl)amino)-BCD, 3-amino-2-naphthoic acid, phthalate, beta-estradiol

Fang, Cheng; Bandaru, Narasimha Murthy; Ellis, Amanda Vera; Voelcker, Nicolas Hans.: (2013) Biosensors & Bioelectronics 42, 632-639