Compound Summary for CID 123591

Fullerene C60

Cite this Record

STRUCTURE VENDORS DRUG INFO PHARMACOLOGY LITERATURE PATENTS BIOACTIVITIES

PubChem CID:	123591
Chemical Names:	Fullerene; Fullerene C60; 99685-96-8; Buckminsterfullerene; C60 Fullerene; Buckyball More...
Molecular Formula:	C_{60}
Molecular Weight:	720.66 g/mol
InChI Key:	XMWRBQBLMFGWIX-UHFFFAOYSA-N
Drug Information:	Therapeutic Uses FDA UNII
Safety Summary:	Laboratory Chemical Safety Summary (LCSS)

Fullerene C60 is a polyhedral CARBON structure composed of around 60-80 carbon atoms in pentagon and hexagon configuration. They are named after Buckminster Fuller because of structural resemblance to geodesic domes. Fullerenes can be made in high temperature such as arc discharge in an inert atmosphere.

from MeSH

C60 fullerene is a fullerene.

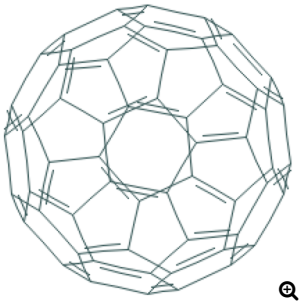
Ontology Summary from ChEBI

PUBCHEM > COMPOUND > FULLERENE C60 *Modify Date: 2019-03-02; Create Date: 2004-09-16*

Contents

1 2D Structure

Search Download Get Image



Magnify

from PubChem

2 3D Status

Conformer generation is disallowed since too many atoms

from PubChem

3 Names and Identifiers

3.1 Computed Descriptors

3.1.1 IUPAC Name

(C60-Ih)[5,6]fullerene

from PubChem

3.1.2 InChI

InChI=1S/C60/c1-2-5-6-3(1)8-12-10-4(1)9-11-7(2)17-21-13(5)23-24-14(6)22-18(8)28-20(12)30-26-16(10)15(9)25-29-19(11)27(17)37-41-31(21)33(23)43-44-34(24)32(22)42-38(28)48-40(30)46-36(26)35(25)45-39(29)47(37)55-49(41)51(43)57-52(44)50(42)56(48)59-54(46)53(45)58(55)60(57)59

from PubChem

3.1.3 InChI Key

XMWRBQBLMFGWIX-UHFFFAOYSA-N

from PubChem

3.1.4 Canonical SMILES

C12=C3C4=C5C6=C1C7=C8C9=C1C%10=C%11C(=C29)C3=C2C3=C4C4=C5C5=C9C6=C7C6=C7C8=C1C1=C

8C%10=C%10C%11=C2C2=C3C3=C4C4=C5C5=C%11C%12=C(C6=C95)C7=C1C1=C%12C5=C%11C4=C3C3=C5C(=C81)C%10=C23

from PubChem

3.2 Molecular Formula

C_{60}

from PubChem

3.3 Other Identifiers

3.3.1 CAS

99685-96-8

from ChemIDplus

3.3.2 UNII

NP9U26B839

from FDA/SPL Indexing Data

3.3.3 Wikipedia

Title	buckminsterfullerene
Description	chemical compound

from Wikipedia

3.4 Synonyms

3.4.1 MeSH Entry Terms

1. Buckminsterfullerene
2. Buckminsterfullerenes
3. Buckyball
4. Buckyballs
5. Fullerene
6. Fullerenes

from MeSH

3.4.2 Depositor-Supplied Synonyms

1. Fullerene
2. Fullerene C60
3. 99685-96-8
4. Buckminsterfullerene
5. C60 Fullerene
6. Buckyball
7. Fullerene 60
8. Fullerene-C60
9. [60]fullerene
10. Footballene
11. UNII-NP9U26B839
12. C60
13. 131159-39-2
14. [5,6]fullerene-C60-Ih
15. (C60-Ih)[5,6]fullerene
16. NP9U26B839
17. Buckminsterfullerene C60
18. (5,6)Fullerene-C60-Ih
19. C60 Compound
20. Fullerene C60, 99.9%
21. (C_{60}-I_{h})[5,6]fullerene
22. soccerballene
23. Fullerite
24. CCRIS 9349
25. buckminsterfulereno
26. Buckminsterfulleren
27. Fullerene-C??
28. 60C
29. [60-Ih]fullerene
30. Fullerene C60 (pure)
31. AC1L3WXP
32. Fullerene Extra
33. Fullerene pow
34. DTXSID40317
35. CHEBI:33128
36. MolPort-023-
37. XMWRBQBLM
38. BCP18982
39. MFCD001514
40. ZINC8554852

from PubChem

4 Chemical and Physical Properties

4.1 Computed Properties

Property Name	Property Value

Molecular Weight	720.66 g/mol
Hydrogen Bond Donor Count	0
Hydrogen Bond Acceptor Count	0
Rotatable Bond Count	0
Complexity	2030
Topological Polar Surface Area	0 A^2
Monoisotopic Mass	720 g/mol
Exact Mass	720 g/mol
XLogP3-AA	18
Compound Is Canonicalized	true
Formal Charge	0
Heavy Atom Count	60
Defined Atom Stereocenter Count	0
Undefined Atom Stereocenter Count	0
Defined Bond Stereocenter Count	0
Undefined Bond Stereocenter Count	0
Isotope Atom Count	0
Covalently-Bonded Unit Count	1

▸ *from PubChem*

4.2 Experimental Properties

4.2.1 Color

Spherical aromatic molecule with a hollow truncated-icosahedron structure, similar to a soccer ball. /C60/

Lewis, R.J. Sr.; Hawley's Condensed Chemical Dictionary 15th Edition. John Wiley & Sons, Inc. New York, NY 2007., p. 188

▸ *from HSDB*

Polyhedral cages made up of entirely five-and six-membered rings ... fullerenes contain 2(10+N) carbon atoms ... the smallest conceivable fullerene is C20, and all fullerenes must contain an even number of carbon atoms.

Cadek M et al; Carbon, 7. Fullerenes and Carbon Nanomaterials. Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: Jan 15, 2010

▸ *from HSDB*

Solutions of C60 fullerene in hydrocarbon solvents are magenta ... C70 fullerene are port-wine red. In some solvents C76 /and C84/ fullerene gives yellow-green solutions ... C82 fullerene has a less greenish tinge. Solutions of C78 fullerene are golden chestnut brown

Cadek M et al; Carbon, 7. Fullerenes and Carbon Nanomaterials. Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: Jan 15, 2010

▸ *from HSDB*

4.2.2 Melting Point

At 260 K, a first-order phase transition from face-centered cubic crystal structure to a simple cubic structure is observed, accompanied by a lattice contraction. ... At 90 K the molecules rearrange to attain the best global minimum. ... At this temperature, the rotational degrees of freedom are frozen, and the solid structure is designated as a pseudo-face-centered cubic crystal structure. C70 Fullerene is rotationally disordered at room temperature and undergoes a transition to a low-temperature phase.

Cadek M et al; Carbon, 7. Fullerenes and Carbon Nanomaterials. Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: Jan 15, 2010

▸ *from HSDB*

4.2.3 Solubility

Virtually insoluble in acetone, ethers, and alcohols

Taylor R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology. (2001). New York, NY: John Wiley & Sons. Online Posting Date: Sept 20, 2002.

▸ *from HSDB*

/C60/ is essentially insoluble in polar solvents, sparingly soluble in alkanes. In aromatic solvents and in carbon disulfide appreciable solubilities are observed.

Cadek M et al; Carbon, 7. Fullerenes and Carbon Nanomaterials. Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: Jan 15, 2010

from HSDB

Solubility (in mg/mL) of (60)fullerene: n-pentane 0.005; n-hexane 0.043; cyclohexane 0.036; n-decane 0.071; decalins 4.6; dichloromethane 0.26; carbon disulfide 7.9; dichloromethane 0.26; chloroform 0.16; tetrachloromethane 0.32; tetrahydrofuran 0.0; benzene 1.7; toluene 2.8; tetralin 16; benzonitrile 0.41; anisole 5.6; 1,2-dichlorobenzene 27; 1-methylnaphthalene 33; 1-chloronaphthalene 41; acetone 0.001; methanol 0.0

Cadek M et al; Carbon, 7. Fullerenes and Carbon Nanomaterials. Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: Jan 15, 2010

from HSDB

The solubility of C70 decreases relative to that of C60 ... roughtly 50% of the values for C60 in toluene, chlorobenzene, 1,2-dichlorobenzene, trichloromethane and hexane. Water solubility is greatly increased by the addition of hydroxyl groups either to the cage (giving fullerenols) or having them present in addends

Li F-B, Wang G-W; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: 19 Apr 2013

from HSDB

Solubilities in various solvents at 25 deg C: ethanol (1.4 mg/L), octanol (42.9 mg/L), distilled octanol (38.9 mg/L), water-saturated octanol (34.7 mg/L), tetrahydrofuran (11 mg/L), toluene (3000 mg/L), water-saturated toluene (2430 mg/L)

Jafvert CT, Kulkarni PP; Environ Sci Technol 42: 5945-5950 (2008)

from HSDB

Calculated solubility in water at 25 deg C = 7.42 ng/L (water-phase of water-octanol), based on measured values in octanol (of octanol-water phase) and octanol-water partition coefficient

Jafvert CT, Kulkarni PP; Environ Sci Technol 42: 5945-5950 (2008)

from HSDB

4.2.4 Density

1.72 g/cu cm /Solid state/

Cadek M et al; Carbon, 7. Fullerenes and Carbon Nanomaterials. Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: Jan 15, 2010

from HSDB

4.2.5 LogP

log Kow = 6.67 /Fullerene C60/

Jafvert CT, Kulkarni PP; Environ Sci Technol 42: 5945-5950 (2008)

from HSDB

4.2.6 Decomposition

Hazardous decomposition products formed under fire conditions. - Carbon oxides. /Fullerene-C60/

Sigma-Aldrich; Material Safety Data Sheet for Fullerene-C60, Product Number: 572500, Version 4.5 (Revision Date 11/13/2012). Available from, as of September 26, 2013: http://www.sigmaaldrich.com/catalog/product/aldrich/572500?lang=en®ion=US

from HSDB

4.3 Spectral Properties

C60 fullerene exhibits strong absorption bands at 213, 257 and 329 nm

Cadek M et al; Carbon, 7. Fullerenes and Carbon Nanomaterials. Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: Jan 15, 2010

from HSDB

At room temperature, the molecules in the lattice rotate at a rate of approximately 1X10+10/sec

Taylor R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology. (2001). New York, NY: John Wiley & Sons. Online Posting Date: Sept 20, 2002.

from HSDB

In the FT-IR spectra, C60 gives four characteristic absorptions at 528, 577, 1183, and 1429 /cm. C70 exhibits 12 peaks at 458, 536, 566, 578, 642, 674, 795, 1087, 1133, 1414, 1431, and 1461 /cm as a result of its lower

symmetry. ... 10 and 27 Raman bands are observed for C60 and C70, respectively

Li F-B, Wang G-W; Kirk-Othmer Encyclopedia of Chemical Technology. (1999-2013). New York, NY: John Wiley & Sons; Fullerenes. Online Posting Date: 19 Apr 2013

from HSDB

4.3.1 Mass Spectrometry

4.3.1.1 General MS

General MS: 1 of 2 (MS)	
MoNA ID	JEL00014
MS Category	Experimental
MS Level	MS2
Precursor Type	M+
precursor m/z	719.99945
Instrument	JMS-S3000
Instrument Type	MALDI-TOFTOF
Ionization Mode	positive
Splash	splash10-00or-0980031000-01e4ecafcf96e6bc85a8
Thumbnail	CLICK TO LOAD...
Submitter	Takaya Satoh, JEOL Ltd.

from MassBank of North America (MoNA)

General MS: 2 of 2 (MS)	
MoNA ID	JEL00013
MS Category	Experimental
MS Level	MS2
Precursor Type	M+
precursor m/z	719.99945
Instrument	JMS-S3000
Instrument Type	MALDI-TOFTOF
Ionization Mode	positive
Splash	splash10-006t-0000019000-37491cdd8db09dfa053a
Thumbnail	CLICK TO LOAD...
Submitter	Takaya Satoh, JEOL Ltd.

from MassBank of North America (MoNA)

4.3.1.2 GC-MS

GC-MS: 1 of 1 (GC-MS Fields)	
NIST Number	115862
Library	Main library
Total Peaks	108
m/z Top Peak	360
m/z 2nd Highest	720
m/z 3rd Highest	721
Thumbnail	CLICK TO LOAD...

from NIST

5 Related Records

5.1 Related Compounds

Same Connectivity	3 records
Same Parent, Connectivity	9 records
Same Parent, Exact	7 records
Mixtures, Components, and Neutralized Forms	14 records
Similar Compounds	56 records

from PubChem

5.2 Substances

5.2.1 Related Substances

All	110 records
Same	83 records
Mixture	27 records

from PubChem

5.2.2 Substances by Category

CLICK TO LOAD...

from PubChem

5.3 Entrez Crosslinks

PubMed	15 records
Protein Structures	3 records
Taxonomy	5 records
Gene	1704 records

from PubChem

6 Chemical Vendors

CLICK TO LOAD...

from PubChem

7 Drug and Medication Information

7.1 Therapeutic Uses

/Experimental Therapy:/ Fullerene (C60), a third carbon allotrope, is a classical engineered material with the potential application in biomedicine. One of the biologically most relevant features of C60 is the ability to quench various free radicals, behaving as a "free radical sponge". Conversely, photosensitization of C60 leads to its transition to a long-lived triplet excited state and the subsequent energy or electron transfer to molecular oxygen, yielding highly reactive singlet oxygen (1O2) or superoxide anion (O2-), respectively. These reactive oxygen species (ROS) react with a wide range of biological targets and are known to be involved in both cellular signaling and cell damage. Therefore, the dual property of fullerenes to either quench or generate cell-damaging ROS could be potentially exploited for their development as cytoprotective or cytotoxic anticancer/antimicrobial agents. However, the attempts to that effect have been hampered by the extremely low water solubility of C60, and by the fact that solubilization procedures profoundly influence the ROS-generating/quenching properties of C60, either through chemical modification or through formation of complex nanoscale particles with different photophysical properties...
Abstract: PubMed

Markovica Z, Trajkobicb; Biomaterials 29 (26): 3561-73 (2008)

▸ *from HSDB*

/Experimental Therapy: Gadolinium metallofullerenol nanoparticles [Gd@C82(OH)22]n particles (22 nm in a saline solution) of a dose level as low as 10-7 mol/kg exhibit a very high antineoplastic efficiency (approximately 60%) in mice. A dose increment of 1 x 10-7 mol/kg increases the tumor inhibition rate 26%. [Gd@C82(OH)22]n particles have a strong capacity to improve immunity and interfere with tumor invasion in normal muscle cells, nearly without toxicity in vivo and in vitro. Unlike conventional antineoplastic chemicals, the high antitumor efficiency of nanoparticles is not due to toxic effects to cells because they do not kill the tumor cells directly and only about 0.05% of the used dose is found in the tumor tissues. Results suggest that fullerene derivatives with proper surface modifications and sizes may /be developed as/ tumor chemotherapeutics of high-efficacy and low-toxicity. /Gadolinium metallofullerenol nanoparticles/
Abstract: PubMed

Chen C et al; Nano Lett 5 (10): 2050-7 (2005)

▸ *from HSDB*

/Experimental Therapy:/ This is the first report on the targeted delivery of fullerene-based low toxic nanocationite particles (porphyrin adducts of cyclohexyl fullerene-C(60)) to treat hypoxia-induced mitochondrial dysfunction in mammalian heart muscle. ... The magnetic isotope effect generated by the release of paramagnetic (25)Mg(2+) from these nanoparticles selectively stimulates the ATP overproduction in the oxygen-depleted cell. ... Because nanoparticles are membranotropic cationites, they will only release the overactivating paramagnetic cations in response to hypoxia-induced acidic shift. The resulting changes in the heart cell energy metabolism result in approximately 80% recovery of the affected myocardium in <24 hr after a single injection (0.03-0.1 LD(50))..... Pharmacokinetics and pharmacodynamics of the nanoparticles suggest their suitability for safe and efficient administration in either single or multi-injection (acute or chronic) therapeutic schemes for the prevention and treatment of clinical conditions involving myocardial hypoxia.
Abstract: PubMed

Amirshahi N et al; Arch Medical Res 39 (6): 549-59 (2008)

▸ *from HSDB*

/Experimental Therapy:/ Oxidative stress plays a major role in acne formation, suggesting that oxygen radical scavengers are potential therapeutic agents. Fullerene is a spherical carbon molecule with strong radical sponge activity; therefore, the effectiveness of fullerene gel in treating acne vulgaris /was studied/. /Investigators/ performed an open trial using a fullerene gel twice a day; at 4 and 8 weeks, the mean number of inflammatory lesions (erythematous papules and pustules) significantly (P < 0.05) decreased from 16.09 +/- 9.08 to 12.36 +/- 7.03 (reduction rate 23.2%) and 10.0 +/- 5.62 (reduction rate 37.8%), respectively. The number of pustules, consisting of accumulation of neutrophils, was significantly (P < 0.05) decreased from 1.45 +/- 1.13 to 0.18 +/- 0.60 (reduction rate 87.6%), and further in vitro assays of sebum production in hamster sebocytes revealed that 75 uM polyvinylpyrrolidone-fullerene inhibits sebum production, suggesting that fullerene suppresses acne through decreasing neutrophil infiltration and sebum production. After treatment for 8 weeks, the water content of the skin significantly (P < 0.05) increased from 51.7 +/- 7.9 to 60.4 +/- 10.3 instrumental units. Therefore, the fullerene gel may help in controlling acne vulgaris with skin care benefit. ...
Abstract: PubMed

Inui S et al; Nanomedicine 7 (2): 238-41 (2011)

▸ *from HSDB*

8 Pharmacology and Biochemistry

8.1 Absorption, Distribution and Excretion

This study was conducted to determine the distribution of (14)C-C60 in the pregnant rat and fetus, and in the lactating rat and off-spring. Four dams were dosed via tail vein injection on gestational day (gd) 15 with 0.28 mg/kg body weight (14)C-C60 (~ 3 uCi per rat) prepared in 5% polyvinylpyrrolidone in saline (PVP), and four dams were dosed with PVP alone. Urine (0-24 hr) and tissues (24 hr) were collected from the dams. Eight lactating rats were dosed on postnatal day (pnd) 8 with 0.36 mg/kg (14)C-C 60 prepared in PVP, and sacrificed at 24 hr or 48 hr after exposure. In the pregnant dams, radioactivity was distributed to the placenta (approximately 2% of the dose), to the fetus (1.0%), and to the female reproductive tract (3.0%). Radioactivity was distributed to the milk (< 1%) and mammary tissue (<1%) in the lactating rats, and to the GI tract (<1%) and liver of the pup (< 1%). For the pregnant dam, radioactivity was distributed to the urine (<2%), feces (2%), blood (0.9% per mL) and plasma (1.7% per mL), brain (< 1%), lung (<1%), heart (<1%), liver (~43%), spleen (4%). In comparison to the pregnant dam, lactating rats had a similar radioactivity distribution to the blood and plasma at 24 hr after exposure (with a 50% decrease by 48 hr), a higher distribution to the lung, and a decreased distribution to the liver. Metabolomics analysis of urine indicated that dams exposed to C60 had a decrease in metabolites derived from the Krebs cycle and an increase in metabolites derived from the urea cycle or glycolysis; with alterations in the levels of some sulfur-containing amino acids and purine/pyrimidine metabolites. This study indicated that C60 can cross the placenta and can be transmitted from mother to offspring via milk.

Snyder R et al; Abstract No. 234. 48th Annual Meeting and ToxExpo, Society of Toxicology, Baltimore, MD (March 15-19, 2009

▸ *from HSDB*

Dermatomed porcine skin was fixed to a flexing device and topically dosed with 33.5 mg/mL of an aqueous solution of a fullerene-substituted phenylalanine (Baa) derivative of a nuclear localization peptide sequence (Baa-Lys(FITC)-NLS). Skin was flexed for 60 or 90 min or left unflexed (control). Confocal microscopy depicted dermal penetration of the nanoparticles at 8 hr in skin flexed for 60 and 90 min, whereas Baa-Lys(FITC)-NLS did not penetrate into the dermis of unflexed skin until 24 hr. TEM analysis revealed fullerene-peptide localization within the intercellular spaces of the stratum granulosum.
Abstract: PubMed

Rouse JG et al; Nano Lett 7 (1): 155-60 (2007)

▸ *from HSDB*

...Both microscopic imaging and biological techniques /were used/ to explore the processes of [C60(C(COOH)2)2]n nanoparticles across cellular membranes and their intracellular translocation in 3T3 L1 and RH-35 living cells. The fullerene nanoparticles are quickly internalized by the cells and then routed to the cytoplasm with punctate localization. Upon entering the cell, they are synchronized to lysosome-like vesicles. The [C60(C(COOH)2)2]n nanoparticles entering cells are mainly via endocytosis with time-, temperature- and energy-dependent manners. The cellular uptake of [C60(C(COOH)2)2]n nanoparticles was found to be clathrin-mediated but not caveolae-mediated endocytosis...

Wei L et al; Nanotechnology 19: 145102 (12 pp) (2008)

▸ *from HSDB*

... An overview of the nanostructure and the physical and chemical characteristics of fullerene-drug derivatives is given. The biological behavior of fullerene derivatives shows their potential to medical application fields

because C(60) is rapidly absorbed by tissues and is excreted through urinary tract and enterons, which reveals low toxicity in vitro and in vivo studies. Nanomedicine has become one of the most promising areas of nanotechnology, while many have claimed its therapeutic use against cancer, human immunodeficiency virus (HIV), and neurodegenerative disorders. Water-soluble C(60) fullerene derivatives that come from chemical modification largely enhance the biological efficacy. The blood-brain barrier (BBB) is a physical barrier composed of endothelial tight junctions that restrict the paracellular permeability. A major challenge facing neuropharmacology is to find compounds that can be delivered into the brain through the bloodstream. Fullerene C(60) was demonstratively able to cross the BBB by hybridizing a biologically active moiety dyad, which provides a promising clue as a pharmacological therapy of neural disorders. /C(60) Fullerene derivatives/

Lin CM, Lu TY; Recent Pat Nanotechnol 6 (2): 105-13 (2012)

▸ *from HSDB*

Pristine fullerenes (C60) in different solvents will be used in many industrial and pharmaceutical manufacturing and derivatizing processes. This report explores the impact of solvents on skin penetration of C60 from different types of industrial solvents (toluene, cyclohexane, chloroform and mineral oil). Yorkshire weanling pigs (n=3) were topically dosed with 500 uL of 200 ug/mL C60 in a given solvent for 24 hr and re-dosed daily for 4 days to simulate the worst scenario in occupational exposures. The dose sites were tape-stripped and skin biopsies were taken after 26 tape-strips for quantitative analysis. When dosed in toluene, cyclohexane or chloroform, pristine fullerenes penetrated deeply into the stratum corneum, the primary barrier of skin. More C60 was detected in the stratum corneum when dosed in chloroform compared to toluene or cyclohexane. Fullerenes were not detected in the skin when dosed in mineral oil. This is the first direct evidence of solvent effects on the skin penetration of pristine fullerenes. The penetration of C60 into the stratum corneum was verified using isolated stratum corneum in vitro; the solvent effects on the stratum corneum absorption of C60

verified using isolated stratum corneum in vitro, the solvent effects on the stratum corneum absorption of C60 were consistent with those observed in vivo. In vitro flow-through diffusion cell experiments were conducted in pig skin and fullerenes were not detected in the receptor solutions by 24 hr. The limit of detection was 0.001 ug/mL of fullerenes in 2 mL of the receptor solutions.
Abstract: PubMed

Xia XR et al; Toxicol Appl Pharmacol 242 (1): 29-37 (2010)

from HSDB

8.2 Biological Half-Life

Fullerenes ... are spherical molecules consisting entirely of carbon atoms (C(x)) to which side chains can be added, furnishing compounds with widely different properties. ... Absorption, distribution and excretion strongly depend on the properties of the side chains. The pristine C(60) has a very long biological half-life, whereas the most water-soluble derivatives are eliminated from the exposed animals within weeks.
Abstract: PubMed

Nielsen G et al; Basic Clin Pharmacol TOxicol 103 (3): 197-208 (2008)

from HSDB

... Male rats /were exposed/ to C60 fullerene nanoparticles (2.22 mg/cu m, 55 nm diameter) and microparticles (2.35 mg/cu m, 0.93 um diameter) for 3 hr a day, for 10 consecutive days using a nose-only exposure system. Nanoparticles were created utilizing an aerosol vaporization and condensation process. Nanoparticles and microparticles were subjected to high-pressure liquid chromatography (HPLC), XRD, and scanning laser Raman spectroscopy, which cumulatively indicated no chemical modification of the C60 fullerenes occurred during the aerosol generation. ... Lung half-lives for C60 fullerene nanoparticles and microparticles were 26 and 29 days, respectively...
Abstract: PubMed

Baker GL et al; Toxicol Sci 101 (1): 122-31 (2008)

from HSDB

9 Use and Manufacturing

9.1 Methods of Manufacturing

Fullerene Synthesis by Combustion. ... Premixed laminar benzene-oxygen-argon flames operated at different pressures, temperatures, and carbon to oxygen ratios have been used. Besides fullerenes and soot, polyaromatic hydrocarbons are formed. The yield of fullerenes and the C70/ C60 ratio strongly depend on the operating mode. The yield of C60 and C70 is in the range of 0.003-9% of the soot mass. Expressed as percentage of fuel carbon, the yields vary from 2X10-4 to 0.3%. The C70/C60 ratio varies over the range 0.26 to 5.7, which is much larger than that observed for graphite-vaporization methods (0.02-0.18). This ratio tends to increase with increasing pressure.

Cadek M et al; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2013). NY, NY: John Wiley & Sons; Carbon, 7. Fullerenes and Carbon Nanomaterials. Online Posting Date: January 15, 2010

from HSDB

Fullerenes can also be obtained by pyrolysis of naphthalene at 1000 deg C in an argon stream. The naphthalene skeleton is a monomer of the C60 structure. The fullerenes are formed by dehydrogenative coupling reactions. Primary reaction products are polynaphthyls with up to seven naphthalene moieties. Full dehydrogenation leads to both C60 and C70 in yields less than 0.5%. Hydrofullerenes such as C60H36 have been observed as side products.

Cadek M et al; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2013). NY, NY: John Wiley & Sons; Carbon, 7. Fullerenes and Carbon Nanomaterials. Online Posting Date: January 15, 2010

from HSDB

The resistive heating of graphite was the first method for producing macroscopic quantities of fullerenes. The apparatus first used ... for the production of C60 was a bell jar connected to a pump and gas inlet. In the jar two graphite rods - one sharpened to a conical point and the other with a flat end - are kept in contact by a spring. The apparatus is evacuated, filled with helium at 14 kPa, and an electric current passed through the rods. This heats the point of contact to 2500 - 3000 deg C and forms a black smoke, which condenses on the bell jar and a smoke catcher. The fullerenes are extracted from the soot with toluene in a yield of 10-15%. The HUFFMAN-KRATSCHMER process has been patented, and the first computer-controlled, fully automated fullerene production systems are commercially available.

Cadek M et al; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2013). NY, NY: John Wiley & Sons; Carbon, 7. Fullerenes and Carbon Nanomaterials. Online Posting Date: January 15, 2010

from HSDB

Arc vaporization of graphite: ... The tips of two sharpened graphite rods are kept at contact-arcing distance, so that the electric power is dissipated in an electric arc rather than in ohmic heating. This method allows efficient evaporation of carbon; the yield of fullerenes is about 15%. The disadvantage of this method is the intense UV radiation originating from the arc plasma. The absorption of UV light by fullerenes produces a triplet state T1 with a lifetime of a few microseconds. In the T1 state, the fullerene is an open-shell system that can readily react with other carbon species Cn to give a nonvaporizable insoluble product.

Cadek M et al; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2013). NY, NY: John Wiley & Sons; Carbon, 7. Fullerenes and Carbon Nanomaterials. Online Posting Date: January 15, 2010

from HSDB

The problem of intense UV radiation is avoided by the use of solar furnaces as fullerene generators, which lead to far lower exposure of the fullerenes to radiation than arc vaporization or resistive heating. In the solar generator ... sunlight is focused by parabolic mirrors onto the tip of a graphite rod under an argon atmosphere in a Pyrex tube. The condensing carbon vapor quickly moves away from the intensive sunlight, cools in the upper regions of the Pyrex tube, and subsequently deposits on the upper walls. Although fullerenes can be obtained in this way, the efficiency of the generator is not very high.

Cadek M et al; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2013). NY, NY: John Wiley & Sons; Carbon, 7. Fullerenes and Carbon Nanomaterials. Online Posting Date: January 15, 2010

from HSDB

Fullerenes can ... be produced by direct inductive heating of a carbon sample in a boron nitride support. Evaporations at 2700 deg C in a helium atmosphere lead to the formation of a fullerene-containing soot, which can be collected on the cooler parts of the Pyrex reactor. This method allows continuous operation by keeping the graphite sample continuously in the heating zone. The evaporation of 1 g of graphite gives 80-120 mg of fullerene extract within 10 min.

Cadek M et al; Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2013). NY, NY: John Wiley & Sons; Carbon, 7. Fullerenes and Carbon Nanomaterials. Online Posting Date: January 15, 2010

from HSDB

... Macroscopic quantities of fullerenes ... were produced by arc discharge of graphite rods in an inert atmosphere of helium at 100 Torr; argon may also be used but the yield is lower. This process produces a fullerene-containing soot (fullerene content about 5%) from which the fullerenes may be extracted with solvents such as toluene, chloroform, etc. Subsequent column chromatography yielded C60 and C70 as magenta and port-wine red solutions, respectively, in either benzene or toluene. Very thin films of these fullerenes are correspondingly mustard yellow and red, but thicker films of each appear black. C60 comprises about 75% of the extract, C70 about 24%, and larger (higher) fullerenes 1%. It is important to exclude all traces of oxygen from the arc-discharge process (which may use either ac or dc current) otherwise significant

amounts of fullerene oxides are produced.

Taylor R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology (2002). NY, NY: John Wiley & Sons, Inc. Online Posting Date: September 20, 2002

from HSDB

Fullerenes with elements or molecules trapped inside them are known as either endohedral or incarfullerenes (this latter being the IUPAC term). They are generally prepared by filling hollow graphite rods with, eg, either a metal, metal carbide, or metal oxide, which on arc-discharge produces fullerenes with the element trapped inside, but the yields are very low (about 0.1%); typical elements are La, Y, Sc, Ce, Eu, etc. The particular fullerene produced depends on the element and reaction conditions, and is usually one that is obtained either in low yield or not at all for empty fullerenes.

Taylor R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology (2002). NY, NY: John Wiley & Sons, Inc. Online Posting Date: September 20, 2002

from HSDB

Nested fullerenes can be produced by electron-beam irradiation of carbon nanoparticles, by laser melting of carbon under high pressure, by shock wave treatment of soot, by the high temperature annealing of nanodiamonds, and by hydrocarbon combustion. The distances between the layers reduces toward the center of the nest, which creates huge internal pressures such that electron-beam irradiation of the cage at 700 deg C converts the inner layers to diamond, which is less space demanding.

Taylor R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology (2002). NY, NY: John Wiley & Sons, Inc. Online Posting Date: September 20, 2002

from HSDB

... /Elongated fullerenes/ may either be single-wall nanotubes (SWNT) (paralleling empty fullerenes) or multi wall nanotubes (MWNT) (paralleling nested fullerenes). Single-wall tubes are of greatest interest and are formed by dc arc discharge of carbon rods containing either cobalt or iron/nickel. Nanotubes can also be formed during combustion and pyrolysis of hydrocarbons, and when finely divided metals are used as catalysts under the latter conditions, the tubes are frequently spiraled.

Taylor R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology (2002). NY, NY: John Wiley & Sons, Inc. Online Posting Date: September 20, 2002

from HSDB

9.2 Formulations/Preparations

For soccer-ball-shaped C60 only one isolated pentagon rule (IPR) is possible; it is the smallest stable fullerene. The rugby-ball-like C70 also has only one IPR and is the next stable homologue, followed by the higher fullerenes C76, C78, C80, C82, C84, C90 ,and C96

Voxtrowsky O, Hirsch A; Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (2008). NY, NY: John Wiley & Sons; Carbon - Fullerenes. Online Posting Date: Jan 15, 2002.

from HSDB

Many of the higher fullerenes are chiral ... the number of possible chiral isomers increases with increasing cage size.

Voxtrowsky O, Hirsch A; Ullmann's Encyclopedia of Industrial Chemistry. 7th ed. (2008). NY, NY: John Wiley & Sons; Carbon - Fullerenes. Online Posting Date: Jan 15, 2002.

from HSDB

10 Identification

10.1 Analytic Laboratory Methods

The actual methods of detection and identification of manufactured nanoparticles in both simple and complex multi-component matrix for assessing biological effects and safety of nanotechnology products have been reviewed. The detection of priority species of biologically active nanoparticles, which include fullerenes, single- and multi-walled carbon nanotubes, nanoparticles of silver, gold, titanium oxide, aluminum, cerium, zinc and silicon, has been given a special attention. The requirements for sample preparation have been discussed. The results of the successful application for the detection of manufactured nanoparticles in bioassays with methods of scanning and transmission electron microscopy, confocal laser scanning microscopy, atomic force microscopy, scanning tunneling microscopy, size exclusion chromatography, field-flow fractionation, electrophoretic, light scattering, spectrophotometry, fluorescent spectroscopy, X-ray and other spectrometry, mass spectrometry, "particle counters", immunochemistry have been reviewed. The possibilities and limitations of different techniques, and their complementarity have been analyzed.
Abstract: PubMed

Gendrikson OD et al; Biofizika 56 (6): 965-94 (2011)

from HSDB

...Fullerenes (C60), have been studied in several different areas and applied widely. Wider application of fullerenes into different products in the recent decades has increased the potential of fullerene releases into the environment. Fullerene research involves physical and chemical characteristics, toxicity, environment fate, and interaction with other pollutions. However, few studies have addressed fullerene quantification in solid matrices. Standardized artificial sediment was prepared following OECD guideline 225, and extracted C60 was quantified by HPLC-UV. A normal shaking method was employed for extraction for two times. Extracts were concentrated and analyzed. Recovery results revealed up to 90.7 +/- 4.5%, 90.0 +/- 3.8%, 93.8 +/- 5.4%, respectively for 1.62, 0.65, and 0.32 ug/g C60 in dry sediment, which shows no significant difference between different concentration levels. Furthermore, extraction efficiency did not show significant difference while using Telfon(TM) tubes (96.5 +/- 6.0%) or silanized glass vessels (90.7 +/- 4.5%). This indicated that relative low cost is required for the method to be initially started in any lab. This technique has also been applied in the determination of C60 in sediment samples collected after a 10 day benthic exposure study. Extraction precision has been increased from 4.5% (S.D.) as the validation value up to 15.4% (RSD%) or more. The increased inhomogeneity by bioturbation and matrix complexity of the sediment after the toxicity test could both lower the extraction precision.
Abstract: PubMed

Wang J et al; Talanta 87: 35-9 (2011)

from HSDB

... Here, /investigators/ report on the development and comparison of liquid chromatography-ultraviolet/visible spectroscopy (LC-UV/vis) and liquid chromatography-mass spectrometry (LC-MS) based detection and quantification methods for commercial fullerols. We achieved good separation efficiency using an amide-type hydrophilic interaction liquid chromatography (HILIC) column (plate number >2000) under isocratic conditions with 90% acetonitrile as the mobile phase. The method detection limits (MDLs) ranged from 42.8 ng/mL (UV detection) to 0.19 pg/mL (using MS with multiple reaction monitoring, MRM). Other MS measurement modes achieved MDLs of 125 pg/mL (single quad scan, Q1) and 1.5 pg/mL (multiple ion monitoring, MI). Each detection method exhibited a good linear response over several orders of magnitude. Moreover, we tested the robustness of these methods in the presence of Suvanee River fulvic acids (SRFA) as an example of organic matter

commonly found in environmental water samples. While SRFA significantly interfered with UV- and Q1-based quantifications, the interference was relatively low using MI or MRM (relative error in presence of SRFA: 8.6% and 2.5%, respectively). This first report of a robust MS-based quantification method for modified fullerenes dissolved in water suggests the feasibility of implementing MS techniques more broadly for identification and quantification of fullerols and other water-soluble fullerene derivatives in environmental samples. /Fullerols/[Chao TC et al; Anal Chem 83 (5): 1777-83 (2011)] Full text: PMC3118260
Abstract: PubMed

from HSDB

Detection methods are necessary to quantify fullerenes in commercial applications to provide potential exposure levels for future risk assessments of fullerene technologies. The fullerene concentrations of five cosmetic products were evaluated using liquid chromatography with mass spectrometry to separate and specifically detect C60 and C70 from interfering cosmetic substances (e.g., castor oil). A cosmetic formulation was characterized with transmission electron microscopy, which confirmed that polyvinylpyrrolidone encapsulated C60. Liquid-liquid extraction of fullerenes from control samples approached 100% while solid-phase and sonication in toluene extractions yielded recoveries of 27-42%. C60 was detected in four commercial cosmetics ranging from 0.04 to 1.1 ug/g, and C70 was qualitatively detected in two samples. A single-use quantity of cosmetic (0.5 g) may contain up to 0.6 ug of C60, demonstrating a pathway for human exposure. Steady-state modeling of fullerene adsorption to biosolids is used to discuss potential environmental releases from wastewater treatment systems.[Benn TM et al; Environ Pollut 159 (5): 1334-42 (2011)] Full text: PMC3725139
Abstract: PubMed

from HSDB

The structures of the two main fullerenes were proved by (13)C NMR spectroscopy, C60 giving just one line (all the carbon atoms are equivalent), whereas C70 gives five lines in a 1:2:1:2:1 ratio, due to the presence in this ratio of the five distinct carbons (labeled a-e).

Taylor, R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology (2002). John Wiley & Sons, Inc. Online Posting Date: September 20, 2002

from HSDB

... The presence of a metal inside a fullerene cage has been demonstrated through the use of synchrotron X-ray powder diffraction.

Taylor, R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology (2002). John Wiley & Sons, Inc. Online Posting Date: September 20, 2002

from HSDB

Characterization Method	Engineered Nanoparticles (ENPs)
Transmission and Scanning Electron Microscopy (TEM and SEM)	Primary particle size and morphology
Energy Dispersive x-Ray Spectroscopy (EDS)	Elemental composition
Electron Diffraction and x-Ray Diffraction	Crystallinity and phase structure
BET Isotherm (Gas Adsorption Measurement)	Specific surface area
Rotating Drum Measurements (EN15051)	Dustiness

Finnish Institute of Occupational Health; Nanoatlas of Selected Engineered Nanoparticles, p10 (2009). Available from, as of September 26, 2013: http://www.ttl.fi/partner/nanosh/progress/Documents/nanosh_nanoatlas.pdf

from HSDB

10.2 Clinical Laboratory Methods

The present study validates the use of liquid-liquid extraction (LLE) and solid-phase extraction (SPE) methods in conjunction with liquid chromatography-mass spectrometry (LC-MS) for the quantitative determination of C(60) in human and synthetic urine as compared with ultrapure water. Glacial acetic acid, which is necessary to prevent emulsions during LLE, inhibited C(60) detection by LC-MS, but this could be mitigated with evaporation. Aqueous C(60) aggregates (nC(60)) were spiked at 180 ug/L into the components of a synthetic urine recipe to determine their individual impacts on extraction and detection. Urea, creatinine, and a complex protein (i.e., gelatin) were found to impair SPE, leading to a low recovery rate of 43 +/- 4% for C(60) spiked into human urine. In contrast, C(60) was consistently recovered from synthetic matrices using LLE, and recovery in human urine was 80 +/- 6%. These results suggest that LLE combined with LC-MS is suitable for studying the clearance of fullerenes from the body. LLE is a robust technique that holds promise for extracting C(60) from other complex biological matrices (e.g., blood, sweat, amniotic fluid) in toxicological studies, enabling a better understanding of the behavior of fullerenes in human and animal systems and facilitating a more comprehensive risk evaluation of fullerenes.[Benn TM et al; Anal Bioanal Chem 399 (4): 1631-9 (2011)] Full text: PMC3711233
Abstract: PubMed

from HSDB

Quantitative liquid-liquid extraction was coupled with liquid chromatography/electrospray ionization mass spectrometry for the quantitative determination of fullerenes from C60 to C98. Isotopically enriched, 13C60, was used as an internal standard. The method was applied to determine the loss of C60 from exposure water solution and uptake of C60 by embryonic zebrafish. The average recovery of C60 from zebrafish embryo extracts and 1% DMSO in aqueous-exposure solutions was 90 and 93%, respectively, and precision, as indicated by the relative standard deviation, was 2 and 7%, respectively. The method quantification limit was 0.40 ug/L and the detection limit was 0.02 ug/L.
Abstract: PubMed

Isaacson CW et al; Anal CHem 79 (23): 9091-7 (2007)

from HSDB

11 Safety and Hazards

11.1 Hazards Identification

11.1.1 GHS Classification

Signal: Warning
GHS Hazard Statements
Aggregated GHS information provided by 36 companies from 7 notifications to the ECHA C&L Inventory. Each notification may be associated with multiple companies.

H315 (25%): Causes skin irritation [Warning Skin corrosion/irritation]
H319 (100%): Causes serious eye irritation [Warning Serious eye damage/eye irritation]
H335 (97.22%): May cause respiratory irritation [Warning Specific target organ toxicity, single exposure; Respiratory tract irritation]

Information may vary between notifications depending on impurities, additives, and other factors. The percentage value in parenthesis indicates the notified classification ratio from companies that provide hazard codes. Only hazard codes with percentage values above 10% are shown.

Precautionary Statement Codes
P261, P264, P271, P280, P302+P352, P304+P340, P305+P351+P338, P312, P321, P332+P313, P337+P313, P362, P403+P233, P405, and P501
(The corresponding statement to each P-code can be found here.)

from European Chemicals Agency (ECHA)

11.1.2 Skin, Eye, and Respiratory Irritations

... Highly purified fullerenes (HPFs) ... HPFs were assessed as "minimally irritating" in the eye-irritation test. ...
Abstract: PubMed

Aoshima H et al; J Toxicol Sci 34 (5): 555-62 (2009)

from HSDB

11.2 Fire Fighting Measures

Suitable extinguishing media: Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide. Special protective equipment for firefighters: Wear self contained breathing apparatus for fire fighting if necessary. /Fullerene-C60/

Sigma-Aldrich; Material Safety Data Sheet for Fullerene-C60, Product Number: 572500, Version 4.5 (Revision Date 11/13/2012). Available from, as of September 26, 2013: http://www.sigmaaldrich.com/catalog/product/aldrich/572500?lang=en®ion=US

from HSDB

11.3 Accidental Release Measures

11.3.1 Cleanup Methods

Personal precautions: Use personal protective equipment. Avoid dust formation. Avoid breathing vapors, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust. Environmental precautions: Do not let product enter drains. Methods and materials for containment and cleaning up: Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal. /Fullerene-C60/

Sigma-Aldrich; Material Safety Data Sheet for Fullerene-C60, Product Number: 572500, Version 4.5 (Revision Date 11/13/2012). Available from, as of September 26, 2013: http://www.sigmaaldrich.com/catalog/product/aldrich/572500?lang=en®ion=US

from HSDB

11.3.2 Disposal Methods

SRP: Wastewater from contaminant suppression, cleaning of protective clothing/equipment, or contaminated sites should be contained and evaluated for subject chemical or decomposition product concentrations. Concentrations shall be lower than applicable environmental discharge or disposal criteria. Alternatively, pretreatment and/or discharge to a permitted wastewater treatment facility is acceptable only after review by the governing authority and assurance that "pass through" violations will not occur. Due consideration shall be given to remediation worker exposure (inhalation, dermal and ingestion) as well as fate during treatment, transfer and disposal. If it is not practicable to manage the chemical in this fashion, it must be evaluated in accordance with EPA 40 CFR Part 261, specifically Subpart B, in order to determine the appropriate local, state and federal requirements for disposal.

from HSDB

SRP: The most favorable course of action is to use an alternative chemical product with less inherent propensity

for occupational exposure or environmental contamination. Recycle any unused portion of the material for its approved use or return it to the manufacturer or supplier. Ultimate disposal of the chemical must consider: the material's impact on air quality; potential migration in soil or water; effects on animal, aquatic, and plant life; and conformance with environmental and public health regulations.

from HSDB

11.3.3 Other Preventative Measures

... The reactor cleanout operation was determined to be an uncontrolled source of engineered nanomaterial (ENM) emissions, apparently due to technicians brushing and scraping unwanted buildup from the inside of the reactor. ...By changing the existing reactor cleanout work practice (vigorously brushing and scraping in multiple directions ... to a more targeted brushing/scraping (toward the inlet of the local exhaust ventilation (LEV)), emissions (both number and mass concentrations) were dramatically reduced... /Nanoparticles/

Methner MM; J Occup Environ Hyg 5 (6): D63-D69 (2008)

from HSDB

SRP: Contaminated protective clothing should be segregated in such a manner so that there is no direct personal contact by personnel who handle, dispose, or clean the clothing. The completeness of the cleaning procedures should be considered before the decontaminated protective clothing is returned for reuse by the workers. Contaminated clothing should not be taken home at the end of shift, but should remain at employee's place of work for cleaning.

from HSDB

Worker training should be part of any complete safety and health program. To reduce nanoparticle exposures, workers should learn how to safely handle nanoparticles, use personal protective equipment, handle work clothes, clean contaminated surfaces, and dispose of spilled nanoparticles. /Nanoparticles/

NIOSH; Safe Nanotechnology in the Workplace. NIOSH Publication No. 2008-112 (February 2008). Available from, as of July 8, 2013: http://www.cdc.gov/niosh/docs/2008-112/

from HSDB

PPE may not be as effective at mitigating dermal exposure. PPE is likely to be less effective against dermal exposure to nanomaterials than macro-sized particles from both human causes (eg, touching face with contaminated fingers) and PPE penetration. /Nanoparticles/

US EPA Science Policy Council Nanotechnology; Nanotechnology White Paper EPA 100/B-07/001 p.49 (February 2007)

from HSDB

The use of good work practices (e.g., handling and transfer practices, using wet methods, cleaning of contaminated surfaces), the education and training of workers, and the use of personal protective equipment (PPE) when needed should help reduce the potential for exposure. /Nanoparticles/

NIOSH; CDC Workplace Safety and Health - Progress Toward Safe Nanotechnology in the Workplace/ A Report from the NIOSH Nanotechnology Research Center p.vii DHHS (NIOSH) Publication No. 2007-123 (June 2007). Available from, as of July 8, 2013: http://www.cdc.gov/niosh/docs/2007-123/pdfs/2007-123.pdf

from HSDB

SRP: Local exhaust ventilation should be applied wherever there is an incidence of point source emissions or dispersion of regulated contaminants in the work area. Ventilation control of the contaminant as close to its point of generation is both the most economical and safest method to minimize personnel exposure to airborne contaminants. Ensure that the local ventilation moves the contaminant away from the worker.

from HSDB

Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday. /Fullerene-C60/

Sigma-Aldrich; Material Safety Data Sheet for Fullerene-C60, Product Number: 572500, Version 4.5 (Revision Date 11/13/2012). Available from, as of September 26, 2013: http://www.sigmaaldrich.com/catalog/product/aldrich/572500?lang=en®ion=US

from HSDB

11.4 Exposure Control and Personal Protection

11.4.1 Protective Equipment and Clothing

Respirators may be necessary when engineering and administrative controls do not adequately prevent exposures. Currently, there are no specific exposure limits for airborne exposures to engineered nanoparticles, although occupational exposure limits exist for larger particles of similar chemical composition. Preliminary evidence shows that for respirator filtration media, particulates as small as 2.5 nm in diameter are efficiently captured, in keeping with single fiber filtration theory. Although this evidence needs confirmation, it suggests that it is likely that NIOSH-certified respirators will be useful for protecting workers from nanoparticle inhalation when properly selected and fit tested as part of a complete respiratory protection program. /Nanoparticles/

NIOSH; CDC Workplace Safety and Health - Progress Toward Safe Nanotechnology in the Workplace/ A Report from the NIOSH Nanotechnology Research Center p.vii DHHS (NIOSH) Publication No. 2007-123 (June 2007). Available from, as of July 8, 2013: http://www.cdc.gov/niosh/docs/2007-123/pdfs/2007-123.pdf

from HSDB

Respirators should be considered if engineering and administrative controls do not control worker exposures to nanoparticles. The decision to use respirators should be based on professional judgment and an assessment of worker exposures and the health risks they pose. /Nanoparticles/

NIOSH; Safe Nanotechnology in the Workplace. NIOSH Publication No. 2008-112 (February 2008). Available from, as of July 8, 2013: http://www.cdc.gov/niosh/docs/2008-112/

from HSDB

Efficient ultrafine particle control devices (e.g., soft x-ray enhanced electrostatic precipitation systems) may have applicability to nanoparticles control. HEPA filters may be effective, and validation of their effectiveness is currently being studied. /Nanoparticles/

US EPA Science Policy Council Nanotechnology; Nanotechnology White Paper EPA 100/B-07/001 p.48 (February 2007)

from HSDB

Engineering controls such as source enclosure (ie, isolating the generation source from the worker) and local exhaust ventilation systems should be effective for capturing airborne nanoparticles. Current knowledge indicates that a well-designed exhaust ventilation system with a high-efficiency particulate air (HEPA) filter should effectively remove nanoparticles. /Nanoparticles/

NIOSH; CDC Workplace Safety and Health - Progress Toward Safe Nanotechnology in the Workplace/ A Report from the NIOSH Nanotechnology Research Center p.vii DHHS (NIOSH) Publication No. 2007-123 (June 2007). Available from, as of July 8, 2013: http://www.cdc.gov/niosh/docs/2007-123/pdfs/2007-123.pdf

from HSDB

For most processes and job tasks, the control of airborne exposure to nanoaerosols can be accomplished using a wide variety of engineering control techniques (eg, exhaust ventilation, process enclosure) similar to those used in reducing exposure to other types of aerosolized particulates. /Nanoparticles/

NIOSH; CDC Workplace Safety and Health - Progress Toward Safe Nanotechnology in the Workplace/ A Report from the NIOSH Nanotechnology Research Center p.vii DHHS (NIOSH) Publication No. 2007-123 (June 2007). Available from, as of July 8, 2013: http://www.cdc.gov/niosh/docs/2007-123/pdfs/2007-123.pdf

from HSDB

Engineering controls have been designed to reduce worker exposures to other particles with sizes similar to those of nanoparticles. Examples include controls for welding fume. These controls are also effective for the manufacturing and fabrication of nanoparticles. /Nanoparticles/

NIOSH; Safe Nanotechnology in the Workplace. NIOSH Publication No. 2008-112 (February 2008). Available from, as of July 8, 2013: http://www.cdc.gov/niosh/docs/2008-112/

from HSDB

Employers should use engineering controls to reduce worker exposures to nanoparticles. These controls include source enclosure (isolating the generation source from the worker) and local exhaust ventilation systems. Exhaust ventilation systems that use high-efficiency particulate air (HEPA) filters are very effective in removing nanoparticles. /Nanoparticles/

NIOSH; Safe Nanotechnology in the Workplace. NIOSH Publication No. 2008-112 (February 2008). Available from, as of July 8, 2013: http://www.cdc.gov/niosh/docs/2008-112/

from HSDB

Evaluations of NIOSH-approved N95 and P100 filtering-facepiece respirators for reducing exposures to nanometer-sized silver aerosol particles supported previous studies which found that such respirators should provide expected levels of protection against nanoparticles, when fitted, maintained, and used properly. In this study, NIOSH researchers found that the respirators were highly efficient in capturing particles that were 4 to 30 nanometers in size, and became increasingly efficient as particles became smaller. This is because smaller particles wander or wobble more in their path as they pass through a filter, and are more likely to be captured or caught by the filter's fibers. Previous reports had suggested that particles less than 20 nanometers would not be captured as efficiently as expected due to thermal effects which would cause the particles to bounce off the fibers during collisions. However, this study found no evidence for thermal rebound of particles as small as 4 nanometers. /Nanoparticles/

NIOSH; NIOSH Nanotechnology Research News Notes: New Papers on PPE, Toxicity; New Partnerships, Award. Available from, as of July 8, 2013: http://www.cdc.gov/niosh/updates/upd-10-02-08.html

from HSDB

... Seven different models of dust masks from local home improvement/hardware stores were challenged with submicron NaCl particles, and initial percentage penetration and resistance levels were measured using two test procedures. A polydisperse aerosol test (PAT) method, similar to the "worst case"conditions used in the NIOSH particulate respirator certification test protocol was used. A monodisperse aerosol test (MAT) method, which utilizes eleven different particle sizes in the range of 20-400 nm, were also used for particle penetration measurements at 30 and 85 L/min flow rates using the TSI 3160. Dust masks were designated as category low-, medium- and high-penetration dust masks based on penetration levels of <5%, 5-25% and >25%, respectively. Data collected using the PAT and the MAT methods showed <5% initial penetration levels for low-penetration dust masks, which is similar to the NIOSH-approved class-95 filtering facepiece respirators. Average penetration levels for medium- and high-penetration dust masks were between 8.9-24.2% and 74.5-96.9%, respectively. Penetration levels of MPPS particles from the MAT correlated with penetration levels from the PAT. Monodisperse MPPS penetration levels from MAT and penetration levels from PAT showed poor correlation with resistance values and no correlation with cost. The results of this study show that dust masks frequently do not provide filtration performance equivalent to that of NIOSH certified devices. Users of dust masks should be cautioned against using them for protection against particulates in the nano- or ultrafine size ranges.

/Nanoparticles/

Rengasamy-S et al; Source J Int Soc Respir Prot 25: 27-41(2008)

from HSDB

Respiratory protection: For nuisance exposures use type P95 (US) or type P1 (EU EN 143) particle respirator. For higher level protection use type OV/AG/P99 (US) or type ABEK-P2 (EU EN 143) respirator cartridges. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU). Hand protection: Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands. Eye protection: Safety glasses with side-shields conforming to EN166 Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU). Skin and

body protection: impervious clothing, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace. /Fullerene-C60/

Sigma-Aldrich; Material Safety Data Sheet for Fullerene-C60, Product Number: 572500, Version 4.5 (Revision Date 11/13/2012). Available from, as of September 26, 2013: http://www.sigmaaldrich.com/catalog/product/aldrich/572500?lang=en®ion=US

from HSDB

12 Toxicity

12.1 Toxicological Information

12.1.1 Interactions

The radioprotective effect of the nanoparticle DF-1, a fullerene with antioxidant properties, /was evaluated. in zebrafish embryos. Zebrafish embryos were exposed to different doses of ionizing radiation ranging from 20 to 80 Gy in the presence and absence of DF-1. Toxicity and radioprotective effects were assessed by monitoring overall survival and morphology as well as organ functions by employing assays to measure kidney excretory function and development of sensory nerve cells (neuromasts). Antioxidant properties of DF-1 were assessed in whole fish. RESULTS: DF-1 had no apparent adverse effects on normal zebrafish morphology or viability

throughout the concentration range tested (1-1,000 umol/L). Ionizing radiation (10-40 Gy) caused time-dependent and dose-dependent perturbations of normal zebrafish morphology and physiology, notably defective midline development resulting in dorsal curvature of the body axis ("curly-up"), neurotoxicity, impaired excretory function, and decreased survival of the exposed embryos. DF-1 (100 umol/L) markedly attenuated overall and organ-specific radiation-induced toxicity when given within 3 hours before or up to 15 minutes after radiation exposure. By contrast, DF-1 afforded no protection when given 30 minutes after ionizing radiation. ... Protection against radiation-associated toxicity using DF-1 in zebrafish embryos was associated with marked reduction of radiation-induced reactive oxygen species.
Abstract: PubMed

Daroczi B et al; Clin Cancer Res 12 (23): 7086-91 (2006)

from HSDB

12.1.2 Antidote and Emergency Treatment

/SRP:/ Immediate first aid: Ensure that adequate decontamination has been carried out. If patient is not breathing, start artificial respiration, preferably with a demand valve resuscitator, bag-valve-mask device, or pocket mask, as trained. Perform CPR if necessary. Immediately flush contaminated eyes with gently flowing water. Do not induce vomiting. If vomiting occurs, lean patient forward or place on the left side (head-down position, if possible) to maintain an open airway and prevent aspiration. Keep patient quiet and maintain normal body temperature. Obtain medical attention. /Poisons A and B/

Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 160

from HSDB

/SRP:/ Basic treatment: Establish a patent airway (oropharyngeal or nasopharyngeal airway, if needed). Suction if necessary. Watch for signs of respiratory insufficiency and assist ventilations if needed. Administer oxygen by nonrebreather mask at 10 to 15 L/min. Monitor for pulmonary edema and treat if necessary ... . Monitor for shock and treat if necessary ... . Anticipate seizures and treat if necessary ... . For eye contamination, flush eyes immediately with water. Irrigate each eye continuously with 0.9% saline (NS) during transport ... . Do not use emetics. For ingestion, rinse mouth and administer 5 mL/kg up to 200 mL of water for dilution if the patient can swallow, has a strong gag reflex, and does not drool ... . Cover skin burns with dry sterile dressings after decontamination ... . /Poisons A and B/

Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 160

from HSDB

/SRP:/ Advanced treatment: Consider orotracheal or nasotracheal intubation for airway control in the patient who is unconscious, has severe pulmonary edema, or is in severe respiratory distress. Positive-pressure ventilation techniques with a bag valve mask device may be beneficial. Consider drug therapy for pulmonary edema ... . Consider administering a beta agonist such as albuterol for severe bronchospasm ... . Monitor cardiac rhythm and treat arrhythmias as necessary ... . Start IV administration of D5W /SRP: "To keep open", minimal flow rate/. Use 0.9% saline (NS) or lactated Ringer's if signs of hypovolemia are present. For hypotension with signs of hypovolemia, administer fluid cautiously. Watch for signs of fluid overload ... . Treat seizures with diazepam or lorazepam ... . Use proparacaine hydrochloride to assist eye irrigation ... . /Poisons A and B/

Currance, P.L. Clements, B., Bronstein, A.C. (Eds).; Emergency Care For Hazardous Materials Exposure. 3Rd edition, Elsevier Mosby, St. Louis, MO 2005, p. 160-1

from HSDB

12.1.3 Human Toxicity Excerpts

/HUMAN EXPOSURE STUDIES/ The safety of highly purified fullerenes (HPFs) for utilization as antioxidants in the cosmetic industry was evaluated by studying the toxicity and effects on ... human epidermal keratinocytes, and human fibroblasts. The HPFs did not induce primary or cumulative skin irritation, skin sensitization, skin photosensitization or contact phototoxicity. No skin reaction was observed in the patch test on human skin. ... Therefore, the HPFs were assessed as "minimally irritating" in the eye-irritation test. By comparing these results with previously published data, /investigators/ concluded that HPFs can be safely used in cosmetic ingredients for human skin application.
Abstract: PubMed

Aoshima H et al; J Toxicol Sci 34 (5): 555-62 (2009)

from HSDB

/GENOTOXICITY/ Recently, manufactured nano/microparticles such as fullerenes (C60), carbon black (CB) and ceramic fiber are being widely used because of their desirable properties in industrial, medical and cosmetic fields. However, there are few data on these particles in mammalian mutagenesis and carcinogenesis. To examine genotoxic effects by C60, CB and kaolin, an in vitro micronuclei (MN) test was conducted with human lung cancer cell line, A549 cells. ... In in vitro genotoxic analysis, increased MN frequencies were observed in A549 cells treated with C60, CB and kaolin in a dose-dependent manner. ... Manufactured nano/microparticles, CB, C60 and kaolin, were shown to be genotoxic in in vitro assay systems.[Totsuka Y et al; Part Fibre Toxicol 6: 23 (2009)] Full text: PMC2745356
Abstract: PubMed

from HSDB

/GENOTOXICITY/ Stable aqueous suspensions of colloidal C60 fullerenes free of toxic organic solvents were

/GENOTOXICITY/ Stable aqueous suspensions of colloidal C60 fullerenes free of toxic organic solvents were prepared by two methods: ethanol to water solvent exchange (EthOH/nC60 suspensions) and extended mixing in water (aqu/nC60 suspensions). The extended mixing method resulted in the formation of larger (dp approximately 178 nm) and less negatively charged (zeta approximately -13.5 mV) nC60 colloids than nC60 prepared by ethanol to water solvent exchange (dp approximately 122 nm, zeta approximately -31.6 mV). Genotoxicity of these suspensions was evaluated with respect to human lymphocytes using single-cell gel electrophoresis assay (Comet assay). The assay demonstrated genotoxicity for both types of suspensions with a strong correlation between the genotoxic response and nC60 concentration, and with genotoxicity observed at concentrations as low as 2.2 ug/L for aqu/nC60 and 4.2 microg/L for EtOH/nC60. The Olive tail moments

(OTM) for these two concentrations were 1.54 +/- 0.24 and 1.34 +/- 0.07, respectively, which in comparison to the negative control OTM of 0.98 +/- 0.17 is statistically different with a p value of at least 0.05. Aqu/nC60 suspensions elicited higher genotoxic response than EthOH/nC60 for the same nC60 concentration. The results represent the first genotoxicity data for colloidal fullerenes produced by simple mixing in water. /Colloidal C60 fullerenes/
Abstract: PubMed

Dhawan A et al; Environ Sci Technol 40 (23): 7394-401 (2006)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Carboxyfullerenes with different adduct numbers and cage sizes are tested as photosensitizers for photodynamic therapy (PDT). The photodynamic efficiency of these carboxyfullerenes depends mainly on the cage size, C(60) versus C(70) , and to a lesser extent on the adduct numbers. In particular, malonic acid modified C(70) fullerenes are more efficient than their C(60) counterparts as photosensitizers, and the mechanism of cell death induced by C(70)-carboxyfullerene under light irradiation is investigated in detail. The results indicate that cell death occurs via necrosis accompanied by membrane blebbing, which is a unique phenomenon for photosensitizer-induced cell death. Since C(70) -carboxyfullerene displays an efficient PDT property and negligible dark cytotoxicity, it is promising for use in PDT applications, especially in vascular capillary diseases usually occurring under the surface. /Malonic acid modified C(70) fullerenes/
Abstract: PubMed

Liu Q et al; Small 8 (13): 2070-7 (2012)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Functionalization of fullerenes with hydroxyl groups (fullerenols) can increase the solubility and potential for cellular interaction, but the health and safety effects of varying degrees of fullerene hydroxylation in biological systems is poorly understood. Existing reports regarding the toxicity and inflammatory potential of fullerenols give conflicting conclusions. To further elucidate the potential for toxicity of fullerenols, human epidermal keratinocytes (HEK) were exposed to fullerenols (low (C60(OH)20), medium (C60(OH)24), and high (C60(OH)32)) at concentrations ranging from 0.000544-42.5 ug/mL for 24 and 48 hr. A statistically significant ($p<0.05$) decrease in viability with alamar Blue (aB) was noted only with C60(OH)32 at 42.5 ug/mL after 24 hr. Nanoparticle (NP) controls showed minimal NP/assay interference of the three fullerenols with the aB viability assay. Normalized IL-8 concentration for C60(OH)20 was not significantly different from control, while C60(OH)24 and C60(OH)32 showed a significant decrease at 24 and 48 hr. These results suggest that different hydroxylation of fullerenes caused no cytotoxicity or inflammation up to 8.55 ug/mL. These findings suggest that extrapolation across similar NP will be dependent upon surface chemistry and concentration which may affect the degree of agglomeration and thus biological effects. /Fullerenols/[Saathoff JGet al; Toxicol In Vitro 25 (8): 2105-12 (2011)] Full text: PMC3217115
Abstract: PubMed

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ High concentrations of manufactured carbon nanoparticles (CNP) are known to cause oxidative stress, inflammatory responses and granuloma formation in respiratory epithelia. To examine the effects of lower, more physiologically relevant concentrations, the human airway epithelial cell line, Calu-3, was used to evaluate potential alterations in transepithelial permeability and cellular function of airway epithelia after exposure to environmentally realistic concentrations of carbon nanoparticles. Three common carbon nanoparticles, fullerenes, single- and multi-wall carbon nanotubes (SWCNT, MWCNT) were used in these experiments. Electrophysiological measurements were performed to assay transepithelial electrical resistance (TEER) and epinephrine-stimulated chloride (Cl(-)) ion secretion of epithelial cell monolayers that had been exposed to nanoparticles for three different times (1 hr, 24 hr and 48 hr) and over a 7 log unit range of

concentrations. Fullerenes did not have any effect on the TEER or stimulated ion transport. However, the carbon nanotubes (CNT) significantly decreased TEER and inhibited epinephrine-stimulated Cl(-) secretion. The changes were time dependent and at more chronic exposures caused functional effects which were evident at concentrations substantially lower than have been previously examined. The functional changes manifested in response to physiologically relevant exposures would inhibit mucociliary clearance mechanisms and compromise the barrier function of airway epithelia.[Banga A et al; Cell Physiol Biochem 29 (1-2): 197-212 (2012)] Full text: PMC3711772
Abstract: PubMed

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Using light microscopy and spectrophotometry, it has been shown that ... water-soluble fullerene C60 cause lysis of human and rat erythrocytes. Fullerene C60 ... partly inhibited the activities of membrane-associated phosphofructokinase and cytoplasmic lactate dehydrogenase in erythrocytes. /Water-soluble fullerene C60/

Solomadin IN et al; Biology Bulletin 35 (4): 436-40 (2008)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Nanomaterials are known to translocate into the circulation and could thus

directly affect vascular endothelial cells (ECs), causing vascular injury that might be responsible for the development of atherosclerosis. To explore the direct effects of nanomaterials on endothelial toxicity, human umbilical vein ECs were treated with 1-100 ug/mL hydroxyl fullerene [C60(OH)24; mean diameter, 7.1 +/- 2.4 nm] for 24 hr. C60(OH)24 induced cytotoxic morphological changes such as cytosolic vacuole formation and decreased cell density in a dose-dependent manner. Lactate dehydrogenase assay revealed that a maximal dose of C60(OH)24 (100 ug/mL) induced cytotoxic injury. Proliferation assay also showed that a maximal dose of C60(OH)24 inhibited EC growth. C60(OH)24 did not seem to induce apoptosis but caused the accumulation of polyubiquitinated proteins and facilitated autophagic cell death. Formation of autophagosomes was confirmed on the basis of Western blot analysis using a specific marker, light chain 3 antibody, and electron microscopy. Chronic treatment with low-dose C60(OH)24 (10 ug/mL for 8 days) inhibited cell attachment and delayed EC growth. In the present study, /investigators/ have examined, ... the toxicity of water-soluble fullerenes to ECs. Although fullerenes changed morphology in a dose-dependent manner, only maximal doses of fullerenes caused cytotoxic injury and/or death and inhibited cell growth. EC death seemed to be caused by activation of ubiquitin-autophagy cell death pathways. /Hydroxyl fullerene/
Abstract: PubMed

Yamawaki H, Iwai N; Am J Physiol Cell Physiol 290 (6): C1495-502 (2006)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Nano-C60 was cytotoxic to human dermal fibroblasts, human liver carcinoma cells (HepG2), and neuronal human astrocytes at doses 50 ppb (LC50=2-50 ppb, depending on cell type) after 48 hr exposure. This water-soluble nano-C60 colloidal suspension disrupts normal cellular function through lipid peroxidation; reactive oxygen species are responsible for the membrane damage. Cellular viability was determined through live/dead staining and LDH release. DNA concentration and mitochondrial activity were not affected by the nano-C60 inoculations to cells in culture. The integrity of cellular membrane was examined by monitoring the peroxy-radicals on the lipid bilayer. Subsequently, glutathione production was measured to assess the cell's reaction to membrane oxidation. The damage to cell membranes was observed both with chemical assays, and confirmed physically by visualizing membrane permeability with high molecular weight dyes. With the addition of an antioxidant, l-ascorbic acid, the oxidative damage and resultant toxicity of nano-C60 was completely prevented. /Colloidal C60 fullerenes/
Abstract: PubMed

Sayes CM et al; Biomaterials 26 (36): 7587-95 (2005)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/The aim of this study was to clarify the biological effects of tetrahydrofuran (THF) suspended C(60) fullerene in comparison to water stirred C(60) fullerene suspensions. Beyond that, ... the human lung epithelial cell line A549 /was analyzed/ as a simplified model for the respiratory tract. ... Water-soluble side products which were formed in THF nC(60) suspension were responsible for the observed acute toxic effects, whereas fullerenes themselves had no negative effect regardless of the preparative route on ... A549 cell in vitro...
Abstract: PubMed

Spohn P et al; Environ Pollut 157 (4): 1134-9 (2009)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ ... In an attempt to understand the biological activity of functionalized C(60), human epidermal keratinocytes (HEK) were exposed to fullerene-based amino acid (Baa) solutions ranging in concentrations of 0.4-0.00004 mg/mL in a humidified 5% CO(2) atmosphere at 37 degrees C. MTT cell viability after 48 hr significantly decreased ($p<0.05$) for concentrations of 0.4 and 0.04 mg/mL. In an additional study, human cytokines IL-6, IL-8, TNF-alpha, IL-1beta, and IL-10 were assessed for concentrations ranging from 0.4-0.004 mg/mL. Media was harvested at 1, 4, 8, 12, 24 and 48 h for cytokine analysis. IL-8 concentrations for the 0.04 mg/mL treatment were significantly greater ($p<0.05$) than all other concentrations at 8, 12, 24, and 48 h. IL-6 and IL-1beta activities were greater at the 24 hr and 48 hr for 0.4 and 0.04 mg/mL. No significant TNF-alpha or IL-10 activity existed at any time points for any of the concentrations. These results indicate that concentrations lower than 0.04 mg/mL initiate less cytokine activity and maintain cell viability. In HEK, Baa concentrations of 0.4 and 0.04 mg/mL decrease cell viability and initiate a pro-inflammatory response.
Abstract: PubMed

Rouse JG et al; Toxicol in Vitro 20 (8): 1313-20 (2006)

from HSDB

/IMMUNOTOXICITY/ C60 nanoparticles, the so-called buckminsterfullerenes, have attracted great attention for medical applications as carriers, enzyme inhibitors or radical scavengers. However, publications evaluating their immunological mechanisms are still rather limited. Therefore, /investigators/ aimed to analyze systematically the in vitro influence of polyhydroxy-C60 (poly-C60) and N-ethyl-polyamino-C60 (nepo-C60) on peripheral blood mononuclear cells (PBMC) from healthy individuals, angling their effect on proliferation, expression of surface markers, and cytokine production. /Investigators/ isolated PBMC from 20 healthy subjects and incubated them in a first step only with poly-C60 or nepo-C60, and in a second step together with recall antigens (purified protein derivative, tetanus toxoid, bacillus Calmette-Guerin). Proliferation was determined by (3)H-thymidine incorporation, activation of PBMC-subpopulations by flow cytometry by measurement of the activation marker CD69, and secretion of T helper cell type 1 (TH1)- (interferon-gamma [IFN-gamma], tumor necrosis factor beta [TNF-beta]), TH2- (interleukin-5 [IL-5], -13, -10) and macrophage/monocyte-related cytokines (IL-1, IL-6, TNF-alpha) into the supernatants by enzyme-linked immunosorbent assay. Both fullerenes did not influence T cell reactivity, with no enhanced expression of CD69 and production of T cell cytokines observed, the CD4/CD8 ratio remaining unaffected. In contrast, they significantly enhanced the release of IL-6 and CD69-expression by CD56 positive natural killer cells. PBMC, which had been cultured together with the three recall antigens were not affected by both fullerenes at all. These data indicate that fullerenes do not interact with T cell reactivity but may activate cells of the innate immune system. Furthermore, they seem to act only on 'naive' cells, which have

not been prestimulated with recall antigens, there are however, large inter individual differences. /Polyhydroxy-C60 (poly-C60) and N-Ethyl-polyamino-C60 (nepo-C60)/[Bunz H et al; Int J Nanomedicine 7: 4571-80 (2013)]
Full text: PMC3428246
Abstract: PubMed

▸ *from HSDB*

/OTHER TOXICITY INFORMATION/ ... Energy-filtered transmission electron microscopy (EFTEM) and scanning transmission electron microscopy (STEM)-based electron tomography /are evaluated/ as techniques for imaging the three-dimensional (3-D) distribution of nanoparticles within cells. /The/ aim was to establish if human monocyte macrophages internalize nanoparticles and to assess whether nanoparticles are modified by cells following uptake. ... 3-D electron tomography revealed several sub-cellular compartments containing C(60) within the cell: secondary lysosomes, along the outer and nuclear membrane and most notably inside the nucleus of the cell. ... EFTEM and STEM-based techniques ... were able to visualize cell structures such as membranes, the mitochondria, ribosomes and the nucleus, without the need for traditional staining techniques. ... The concentrations of C(60) used in this study were not toxic and were chosen to study which sub-cellular compartments accumulated C(60).
Abstract: PubMed

Porter AE et al; Acta Biomat 2 (4): 409-19 (2006)

▸ *from HSDB*

/OTHER TOXICITY INFORMATION/ Carbon black (CB), single-walled carbon nanotubes (SWCNT), fullerenes (C60), nC60, and quantum dots (QD) were used in vitro to determine their cytotoxicity with classical toxicity assays. Classical dye-based viability assays such as neutral red (NR) and MTT produce invalid results when treated with some nanomaterials (NM) due to interactions and/or adsorption of the dye or dye product. In this study, human epidermal keratinocytes (HEK) were exposed in vitro to CB, SWCNT, C60, nC60, QD, and Min-U-Sil 5 that served as a particle control to assess viability with Trypan Blue (TB), Live/Dead (LD), calcein AM (CAM), NR, MTT, Celltiter 96, Aqueous One (96 AQ), alamar Blue (aB), Celltiter-Blue (CTB), CytoTox OneTM (CTO), and flow cytometry. Viability linearity (R2 value) for each assay was determined with HEK plated at concentrations ranging from 0 to 25,000 cells per well in 96 well plates. HEK were treated with serial dilutions of each NM for 24 hr and assessed with each of the viability assays above. Dye-based assays varied a great deal, depending on the interactions of the dye/dye product with the type of NM. Based on the above studies, the optimal assay was 96 AQ. Unlike small molecules, NM can interact with different assay markers to cause variable results with these classical assays and might not be suitable for assessing cytotoxicity of engineered NM. Therefore, multiple assays may be required when determining nanoparticle cytotoxicity for risk assessment.

Inman AO et al; Abstract No. 875. 48th Annual Meeting and ToxExpo, Society of Toxicology, Baltimore, MD (March 15-19, 2009)

▸ *from HSDB*

12.1.4 Non-Human Toxicity Excerpts

/LABORATORY ANIMALS: Acute Exposure/ The safety of highly purified fullerenes (HPFs) for utilization as antioxidants in the cosmetic industry was evaluated by studying the toxicity and effects on laboratory animals... The HPFs did not induce primary or cumulative skin irritation, skin sensitization, skin photosensitization or contact phototoxicity. ... In the primary eye-irritation test on rabbits, conjunctival redness and corneal epithelial defects were observed in all animals of the eye-unwashed group at 1 and 24 hr after application, but disappeared by 48 hr after application. The irritation may have been caused by administration of insoluble fullerene powder. Therefore, the HPFs were assessed as "minimally irritating" in the eye-irritation test. By comparing these results with previously published data, /investigator/ concluded that HPFs can be safely used in cosmetic ingredients for human skin application.
Abstract: PubMed

Aoshima H et al; J Toxicol Sci 34 (5): 555-62 (2009)

▸ *from HSDB*

/LABORATORY ANIMALS: Acute Exposure/ Hydroxylated fullerenes (C60OH(x)) or fullerols are water-soluble carbon nanoparticles that have been explored for potential therapeutic applications. This study assesses acute in vivo tolerance in 8-wk-old female Sprague-Dawley rats to intravenous (iv) administration of 10 mg/kg of well-characterized C60(OH)30. Complete histopathology and clinical chemistries are assessed at 8, 24, and 48 hr after dosing. Minor histopathology changes are seen, primarily in one animal. No clinically significant chemistry changes were observed after treatment. These experiments suggest that this fullerol was well tolerated after iv administration to rats. /Hydroxylated fullerenes/[Monteiro-Riviere NA et al; J Toxicol Environ Health A 75 (7): 367-73 (2013)] Full text: PMC3418876
Abstract: PubMed

▸ *from HSDB*

/LABORATORY ANIMALS: Acute Exposure/ ... This study was performed to examine the potential irritating and sensitizing effects of fullerenes on the skin and eyes. The dermal and eye irritation study was performed using rabbits according to the Organisation for Economic Co-operation and Development (OECD) Guidelines 404 and 405, respectively. The skin sensitization study was carried out in accordance to the OECD Guideline 406 using guinea pigs. The concentrations of the fullerenes in the test substances were the maximum allowable for administration. Fullerenes were applied at 50 mg in dermal irritation, 40 mg in skin sensitization, and 100 mg in eye irritation studies. No dermal responses, including erythema/eschar or edema, were found in rabbits treated with fullerenes. No rabbits exhibited corneal opacity, abnormality of the iris, or chemosis eye at any time point after the application of fullerenes. Fullerenes caused conjunctival redness and blood vessel hyperemia at 1 hr,

but not at 24 hr. No erythema or edema was observed after the challenge with fullerenes in the fullerene-treated guinea pigs. Reversible minimal potential for acute irritation of the eyes was induced by fullerenes, but neither irritation nor sensitization was caused on the skin. Although the present study provided initial information on the acute irritation and acute sensitization of highly purified C(60)fullerenes, information on the toxicological effects of fullerenes and their derivatives is still limited. Further information is needed to clarify the potential for toxicity given the complex nature of fullerenes and their derivatives.
Abstract: PubMed

Ema M et al; Cutan Ocul Toxicol 32 (2): 128-34 (2013)

from HSDB

/LABORATORY ANIMALS: Acute Exposure/ ...It was reported that doses of an aggregated form of underivatized C60, termed nano-C60, were 3-4 orders of magnitude more toxic to human dermal fibroblasts, lung epithelial cells, and normal human astrocytes when compared to identical exposures of these cell types to a fully derivatized, highly water-soluble derivative, C60(OH)24. Accordingly, the aim of this study was to test and validate these in vitro findings by comparing the in vivo pulmonary toxicity effects in rats of intratracheally instilled nano-C60 and C60(OH)24. In two combined studies, groups of rats were instilled with doses of either 0.2, 0.4, 1.5, or 3.0 mg/kg of nano-C60, C60(OH)24, or alpha-quartz particle types using Milli-Q water as the vehicle. Subsequently, the lungs of vehicle and particle-exposed rats were assessed using bronchoalveolar lavage (BAL) fluid biomarkers, oxidant and glutathione endpoints, airway and lung parenchymal cell proliferation methods, and histopathological evaluation of lung tissue at 1 day, 1 week, 1 month, and 3 months postinstillation exposure. Exposures to both nano-C60 or water-soluble C60(OH)24 produced only transient inflammatory and cell injury effects at 1 day postexposure (pe) and were not different from water instilled controls at any other postexposure time periods. An increase in lipid peroxidation endpoints vs controls was measured in BAL fluids of rats exposed to 1.5 and 3 mg/kg of nano-C60 at 1 day and 3 month pe time points. In addition, no adverse lung tissue effects were measured at 3 months postinstillation exposures to the highest dose of the two types of fullerenes. In contrast, pulmonary exposures to quartz particles in rats produced dose-dependent lung inflammatory responses characterized by neutrophils and foamy lipid-containing alveolar macrophage

accumulation as well as evidence of early lung tissue thickening consistent with the development of pulmonary fibrosis. The results demonstrated little or no difference in lung toxicity effects between the two fullerene samples when compared to controls, and these data are not consistent with the previously reported in vitro effects. The findings exemplify both the difficulty in interpreting and extrapolating in vitro toxicity measurements to in vivo effects and highlight the complexities associated with probing the relevant toxicological responses of fullerene nanoparticle systems.
Abstract: PubMed

Sayes CM et al; Nano Lett 7 (8): 2399-406 (2007)

from HSDB

/LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ /Investigators/ used fullerenes, whose dispersion at the nano-level was stabilized by grinding in nitrogen gas in an agitation mill, to conduct an intratracheal instillation study and an inhalation exposure study. Fullerenes were individually dispersed in distilled water including 0.1% Tween 80, and the diameter of the fullerenes was 33 nm. These suspensions were directly injected as a solution in the intratracheal instillation study. The reference material was nickel oxide in distilled water. Wistar male rats intratracheally received a dose of 0.1 mg, 0.2 mg, or 1 mg of fullerenes and were sacrificed after 3 days, 1 week, 1 month, 3 months, and 6 months. In the inhalation study, Wistar rats were exposed to fullerene agglomerates (diameter: 96 +/- 5 nm; 0.12 +/- 0.03 mg/cu m; 6 hours/days for 5 days/week) for 4 weeks and were sacrificed at 3 days, 1 month, and 3 months after the end of exposure. The inflammatory responses and gene expression of cytokine-induced neutrophil chemoattractants (CINCs) were examined in rat lungs in both studies. In the intratracheal instillation study, both the 0.1 mg and 0.2 mg fullerene groups did not show a significant increase of the total cell and neutrophil count in bronchial alveolar lavage fluid (BALF) or in the expression of CINC-1,-2alphabeta and-3 in the lung, while the high-dose, 1 mg group only showed a transient significant increase of neutrophils and expression of CINC-1,-2alphabeta and -3. In the inhalation study, there were no increases of total cell and neutrophil count in BALF, CINC-1,-2alphabeta and-3 in the fullerene group. These data in intratracheal instillation and inhalation studies suggested that well-dispersed fullerenes do not have strong potential of neutrophil inflammation.[Morimoto Y et al; Part Fibre Toxicol 7: 4 (2010)] Full text: PMC2848185
Abstract: PubMed

from HSDB

/LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ ... Male rats /were exposed/ to C60 fullerene nanoparticles (2.22 mg/cu m, 55 nm diameter) and microparticles (2.35 mg/cu m, 0.93 um diameter) for 3 hr a day, for 10 consecutive days using a nose-only exposure system. Nanoparticles were created utilizing an aerosol vaporization and condensation process. Nanoparticles and microparticles were subjected to high-pressure liquid chromatography (HPLC), XRD, and scanning laser Raman spectroscopy, which cumulatively indicated no chemical modification of the C60 fullerenes occurred during the aerosol generation. At necropsy, no gross or microscopic lesions were observed in either group of C60 fullerene exposures rats. Hematology and serum chemistry results found statistically significant differences, although small in magnitude, in both exposure groups. Comparisons of bronchoalveolar (BAL) lavage fluid parameters identified a significant increase in protein concentration in rats exposed to C60 fullerene nanoparticles. BAL fluid macrophages from both exposure groups contained brown pigments, consistent with C60 fullerenes. C60 lung particle burdens were greater in nanoparticle-exposed rats than in microparticle-exposed rats. The calculated lung deposition rate and deposition fraction were 41 and 50% greater, respectively, in C60 fullerene nanoparticle-exposed group than the C60 fullerene microparticle-exposed group. Lung half-lives for C60 fullerene nanoparticles and microparticles were 26 and 29 days, respectively...
Abstract: PubMed

Baker GL et al; Toxicol Sci 101 (1): 122-31 (2008)

from HSDB

from HSDB

/LABORATORY ANIMALS: Subchronic or Prechronic Exposure/ Fullerene C60 is a 1 nm diameter molecule that can aggregate into larger crystals up to several mm in size. C60 was selected for study to evaluate the hypothesis that decrease in particle size leads to an increase in potency of toxicity of nanoscale materials. In this study we evaluated the effect of inhalation exposure to two different sized particles of C60. Wistar-Han rats and B6C3F1 mice were exposed by nose-only inhalation to two sizes of C60 (0.05 um or 1um) 3 hours per day 5 days per week for 90 days. Exposure concentrations were 0, 0.5, 2.5 mg/cu m for 0.05 um C60, and 0, 5, 15 and 30 mg/cu m for the 1 um C60. A complete necropsy and histopathological evaluation were conducted on all animals. Tissue distribution of C60 as well as lung clearance was also determined. In addition effects of exposure on organ weights, clinical chemistry, hematology, micronucleus formation, and effects on the reproductive tissues and immune system/function were also evaluated. There were no biologically significant exposure-related changes in these parameters in rats or mice exposed to either 0.05 um or 1 um C60. Pathological effects were generally restricted to increased lung pigmentation (attributable to lung deposition of C60) and histiocyte infiltration (compensatory response to clear C60 from the lung). In both rats and mice, there was a shift in inflammatory cell populations in lung lavage fluid. These findings indicate that inhalation exposure to C60 particles caused negligible toxicity and that a decrease in particle size to the nanoscale did not exacerbate toxicity. These data are consistent with the observed lack of toxicity of C60 after both shorter-term exposures and in studies using intratracheal instillation.

Walker NJ et al; Abstract No. 233. 48th Annual Meeting and ToxExpo, Society of Toxicology, Baltimore, MD (March 15-19, 2009)

from HSDB

/LABORATORY ANIMALS: Developmental or Reproductive Toxicity/ This paper reviews studies in vivo and in vitro on the reproductive and developmental toxicity of manufactured nanomaterials including metallic and metal oxide-based particles, fullerenes (C(60)), carbon black (CB), and luminescent particles. Studies in vivo showed increased allergic susceptibility in offspring of mouse dams intranasally insufflated with respirable-size titanium dioxide (TiO(2)), adverse effects on spermatogenesis and histopathological changes in the testes and changes in gene expression in the brain of mouse offspring after maternal subcutaneous injection of TiO(2) nanoparticles, transfer to rat fetuses of radiolabeled gold nanoparticles and C(60) after maternal intravenous injection, death and morphological abnormalities in mouse embryos after maternal intraperitoneal injection of C(60), and adverse effects on spermatogenesis in mouse offspring after maternal intratracheal instillation of CB nanoparticles. Studies in vitro revealed that TiO(2) and CB nanoparticles affected the viability of mouse Leydig cells, that gold nanoparticles reduced the motility of human sperm, that silver, aluminum, and molybdenum trioxide were toxic to mouse spermatogonia stem cells, that silica nanoparticles and C(60) inhibited the differentiation of mouse embryonic stem cells and midbrain cells, respectively, and that cadmium selenium-core quantum dots inhibited pre- and postimplantation development of mouse embryos. ...
Abstract: PubMed

Ema M et al; Reprod Toxicol 30 (3): 343-52 (2010)

from HSDB

/LABORATORY ANIMALS: Developmental or Reproductive Toxicity/ The present paper summarizes /information on/ ... the developmental toxicity of stable buckminsterfullerene aggregates suspended in water (nC60) using zebrafish (Danio rerio) as a vertebrate model. Zebrafish embryo survival, hatching rate, heartbeat, and pericardial edema were noted and described within 96 hr of exposure. Fullerol (a hydroxylated C60 derivative, C60(OH)16-18) at 50 mg/L did not exert toxicity to zebrafish embryos. In contrast, nC60 at 1.5 mg/L delayed zebrafish embryo and larval development, decreased survival and hatching rates, and caused pericardial edema. Toxicity was mitigated by adding an antioxidant (glutathione), which suggests that a free radical-induced mechanism or another form of oxidative stress played a role in developmental toxicity.
Abstract: PubMed

Zhu X et al; Environ Toxicol Chem 26 (5): 976-9 (2007)

from HSDB

/LABORATORY ANIMALS: Neurotoxicity/ Fullerenes are condensed ring aromatic compounds with extended pi systems; they have unique cage structures. Current studies suggest that several fullerene derivatives have neuroprotective effects, and it is expected that fullerenes will be useful in drug delivery system and novel medical devices targeting the brain. However, little is known about the effects of fullerenes and its derivative on brain function. We examined the effect of fullerene(OH)24 on the central nervous system in this study. In a V79 colony assay, the IC50 of fullerene(OH)24 was 1.74 ug/mL. In an MTT assay, fullerene(OH)24 reduced proliferation of normal human astrocytes obviously. In an vivo study, 0.25 mg/kg(-1) of fullerene(OH)24 was injected into the lateral ventricle of rat brains. The intracerebral injection of fullerene(OH)24 remarkably decreased body weight and locomotor behavior of rats on day 1, but drastically increased locomotor behavior on day 7. The intracerebral injection of fullerene(OH)24 changed the monoamine concentration greatly on day 1 and slightly on day 30 after the injection. These results suggest that intracerebral injection of fullerene(OH)24 had strong and acute effects on the central nervous system, but that the effects were not permanent. In conclusion, /the data/ suggest that fullerene's derivative, fullerene(OH)24 had toxic effects on brain cells and that intracerebral injection of fullerene(OH)24 had acute harmful effects on brain monoamines neurotransmission and locomotor activity.
Abstract: PubMed

Yamada T et al; J Nanosci Nanotechnol. 10 (1): 604-11 (2010)

from HSDB

/GENOTOXICITY/ C60 fullerenes and single-walled carbon nanotubes (SWCNT) are projected to be used in medicine and consumer products with potential human exposure. The hazardous effects of these particles are expected to involve oxidative stress with generation of oxidatively damaged DNA that might be the initiating event in the development of cancer. In this study, the effect of a single oral administration of C60 fullerenes and SWCNT /was investigated/. /Investigators/ measured the level of oxidative damage to DNA as the premutagenic

SWCNT /was investigated/. /Investigators/ measured the level of oxidative damage to DNA as the premutagenic 8-oxo-7,8-dihydro-2'-deoxyguanosine (8-oxodG) in the colon mucosa, liver, and lung of rats after intragastric administration of pristine C60 fullerenes or SWCNT (0.064 or 0.64 mg/kg body weight) suspended in saline solution or corn oil. The regulation of DNA repair systems toward 8-oxodG in liver and lung tissue /was investigated/. Both doses of SWCNT increased the levels of 8-oxodG in liver and lung. Administration of C60 fullerenes increased the hepatic level of 8-oxodG, whereas only the high dose generated 8-oxodG in the lung. /Investigators/ detected no effects on 8-oxodG in colon mucosa. Suspension of particles in saline solution or corn oil yielded a similar extent of genotoxicity, whereas corn oil per se generated more genotoxicity than the particles. Although there was increased mRNA expression of 8-oxoguanine DNA glycosylase in the liver of C60 fullerene-treated rats, /investigators/ found no significant increase in repair activity. Oral exposure to low doses of C60 fullerenes and SWCNT is associated with elevated levels of 8-oxodG in the liver and lung, which is likely to be caused by a direct genotoxic ability rather than an inhibition of the DNA repair system.[Folkmann JK et al; Environ Health Perspect 117 (5): 703-8 (2009)] Full text: PMC2685830
Abstract: PubMed

▸ *from HSDB*

/GENOTOXICITY/ Recently, manufactured nano/microparticles such as fullerenes (C60), carbon black (CB) and ceramic fiber are being widely used because of their desirable properties in industrial, medical and cosmetic fields. However, there are few data on these particles in mammalian mutagenesis and carcinogenesis. To examine genotoxic effects by C60, CB and kaolin, ... DNA damage and mutations were analyzed by in vivo assay systems using male C57BL/6J or gpt delta transgenic mice which were intratracheally instilled with single or multiple doses of 0.2 mg per animal of particles. ... These three nano/microparticles also induced DNA damage in the lungs of C57BL/6J mice measured by comet assay. Moreover, single or multiple instillations of C60 and kaolin, increased either or both of gpt and Spi- mutant frequencies in the lungs of gpt delta transgenic mice.

Mutation spectra analysis showed transversions were predominant, and more than 60% of the base substitutions occurred at G:C base pairs in the gpt genes. The G:C to C:G transversion was commonly increased by these particle instillations. Manufactured nano/microparticles, CB, C60 and kaolin, were shown to be genotoxic in ... in vivo assay systems.[Totsuka Y et al; Part Fibre Toxicol 6: 23 (2009)] Full text: PMC2745356
Abstract: PubMed

▸ *from HSDB*

/GENOTOXICITY/ /Investigators/ evaluated the safety of water-soluble polymer-enwrapped fullerenes (PVP/fullerenes) as antioxidants in cosmetic and pharmaceutical preparations by studying the genotoxicity, phototoxicity, and pro-oxidant effects of these fullerenes. These materials were not mutagenic to any of the tested bacterial strains and did not induce chromosomal aberrations in cultured mammalian cells. The PVP/fullerenes did not exhibit cytotoxicity under ultraviolet or sham irradiation in the alternative phototoxicity test. Moreover, they did not show any pro-oxidant effect in the presence of Fe(2+) or Cu(2+). Thus, /investigators/ concluded that PVP/fullerenes are safe for use in cosmetic and pharmaceutical applications. / PVP/fullerenes/
Abstract: PubMed

Aoshima H et al; J Toxicol Sci 35 (3): 401-9 (2010)

▸ *from HSDB*

/GENOTOXICITY/ While there is growing concern over the potential detrimental impact of engineered nanoparticles (ENPs) on the natural environment, little is known about their interactions with other contaminants. In the present study, marine mussels (Mytilus sp.) were exposed for 3 days to C(60) fullerenes(C(60); 0.10-1 mg L(-1)) and a model polycyclic aromatic hydrocarbon (PAH), fluoranthene (32-100 ug L(-1)), either alone or in combination. The first two experiments were conducted by exposing the organisms to different concentrations of C(60) and fluoranthene alone, in order to determine the effects on total glutathione levels (as a measure of generic oxidative stress), genotoxicity (DNA strand breaks using Comet assay in haemocytes), DNA adduct analyses (using (32)P-postlabelling method) in different organs, histopathological changes in different tissues (i.e. adductor muscle, digestive gland and gills) and physiological effects (feeding or clearance rate). Subsequently, in the third experiment, a combined exposure of C(60) plus fluoranthene (0.10 mg L(-1) and 32 ug L(-1), respectively) was carried out to evaluate all endpoints mentioned above. Both fluoranthene and C(60) on their own caused concentration-dependent increases in DNA strand breaks as determined by the Comet assay. Formation of DNA adducts however could not be detected for any exposure conditions. Combined exposure to C(60) and fluoranthene additively enhanced the levels of DNA strand breaks along with a 2-fold increase in the total glutathione content. In addition, significant accumulation of C(60) was observed in all organs, with highest levels in digestive gland (24.90 +/- 4.91ug C(60) g(-1) ww). Interestingly, clear signs of abnormalities in adductor muscle, digestive gland and gills were observed by histopathology. Clearance rates indicated significant differences compared to the control with exposure to C(60), and C(60)/fluoranthene combined treatments, but not after fluoranthene exposure alone. This study demonstrated that at the selected concentrations, both C(60) and fluoranthene evoke toxic responses and genetic damage. The combined exposure produced enhanced damage with additive rather than synergistic effects.
Abstract: PubMed

Al-Subiai SN et al; Mutat Res 745 (1-2): 92-103 (2012)

▸ *from HSDB*

/GENOTOXICITY/ Carbon nanomaterials such as carbon nanotubes, graphene, and fullerenes (C(60)) are widely used in industry. Because of human health concerns, their toxic potential has been examined in vivo and in vitro. Here we used mammalian cells to examine the in vitro clastogenicity as well as the phototoxicity of C(60). While C(60) induced no structural chromosome aberrations in CHL/IU cells at up to 5mg/mL (the maximum

concentration tested), it significantly induced polyploidy at 2.5 and 5mg/mL with and without metabolic activation. In BALB 3T3 cells, C(60) showed no phototoxic potential but the anatase form of titanium oxide did. Since insoluble nanomaterials cause polyploidy by blocking cytokinesis rather than by damaging DNA, we

concluded that the polyploidy induced by C(60) in CHL/IU cells was probably due to non-DNA interacting mechanisms.
Abstract: PubMed

Honma M et al; Mutat Res 749 (1-2): 97-100 (2012)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/The most known fullerenes are spherical carbon compounds composed of 60 carbon atoms. C(60) fullerenes have shown biochemical and biomedical properties in the last years such as blockade of apoptosis and neuroprotection. The nucleoside adenosine has a neuroprotective role mainly due to inhibition of glutamate release, which is a neurotransmitter related to excitotoxicity and cell death. In the present work, /the investigators/ have determined the presence of adenosine receptors in SK-N-MC cells, a neuroepithelioma human cell line, and analyzed the effect of fullerenes in these receptors by using radioligand binding, immunoblotting, and quantitative real time PCR assays. Results demonstrated that SK-N-MC cells endogenously express adenosine receptors. Fullerene exposure of these cells did not affect cell viability measured by MTT reduction assay. However, adenosine A(1) and A(2A) receptors were both increased in SK-N-MC cells after treatment. These results suggest for the first time the modulation of adenosine receptors after C(60) fullerenes exposure.[Giust D et al; ACS Chem Neurosci 2 (7): 363-9 (2011)] Full text: PMC3369736
Abstract: PubMed

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Rapid advances are being made in the creation and use of nanomaterials, but little is known about the impact these materials might have on key microbial functions if introduced into the environment. Previous studies have generated conflicting results with respect to the impact of fullerenes on microbial activity. In the present study, Salmonella typhimurium TA100 was selected as a model microbial system with which to investigate further the impact of C(60) aggregates on microbial growth, mutagenicity, and global transcript expression. Aggregates of C(60) predominantly less than 100 nm significantly impacted Salmonella growth at concentrations of >/= 0.5 mg/L. In addition, C(60) aggregates also displayed mutagenic potential at concentrations >/= 0.1 mg/L. Transcript expression analysis of S. typhimurium TA100 exposed to C(60) for 24 hr indicated that 271 transcripts had significant differential expression relative to controls with twofold or more change. Of particular interest was the increased expression of transcripts coding for proteins involved in energy metabolism, amino acid biosynthesis, transcription, and DNA metabolism, and the decreased expression of transcripts coding for proteins involved in protein fate, transport, and binding and bacterial secretion systems. Collectively, these data indicate that C(60) interacts with the outer membrane of S. typhimurium TA100, resulting in delayed growth and mutagenicity, most likely by interfering with key transport functions and inducing a stress response, respectively.
Abstract: PubMed

Hancock DE et al; Environ Toxicol Chem 31 (7): 1438-44 (2012)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Water soluble fullerenes, such as the hydroxylated fullerene, fullerenol (C60OHx), are currently under development for diagnostic and therapeutic biomedical applications in the field of nanotechnology. These molecules have been shown to undergo urinary clearance, yet there is limited data available on their renal biocompatibility. Here /investigators/ examine the biological responses of renal proximal tubule cells (LLC-PK1) exposed to fullerenol. Fullerenol was found to be cytotoxic in the millimolar range, with viability assessed by the sulforhodamine B and trypan blue assays. Fullerenol-induced cell death was associated with cytoskeleton disruption and autophagic vacuole accumulation. Interaction with the autophagy

pathway was evaluated in vitro by Lysotracker Red dye uptake, LC3-II marker expression and TEM. Fullerenol treatment also resulted in coincident loss of cellular mitochondrial membrane potential and ATP depletion, as measured by the Mitotracker Red dye and the luciferin-luciferase assays, respectively. Fullerenol-induced ATP depletion and loss of mitochondrial potential were partially ameliorated by co-treatment with the autophagy inhibitor, 3-methyladenine. In vitro fullerenol treatment did not result in appreciable oxidative stress, as measured by lipid peroxide and glutathione content. Based on these data, it is hypothesized that cytoskeleton disruption may be an initiating event in fullerenol cytotoxicity, leading to subsequent autophagy dysfunction and loss of mitochondrial capacity. As nanoparticle-induced cytoskeleton disruption, autophagic vacuole accumulation and mitochondrial dysfunction are commonly reported in the literature, the proposed mechanism may be relevant for a variety of nanomaterials. /Fullerenol/[Johnson-Lyles DN et al; Toxicol Appl Pharmacol. 248 (3): 249-58 (2010)] Full text: PMC2949473
Abstract: PubMed

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ The cytotoxic effects of hydroxylated fullerenes, also termed fullerenols or fullerols [C(60)(OH)(n)], which are known nanomaterials and water-soluble fullerene derivatives, were studied in freshly isolated rat hepatocytes. The exposure of hepatocytes to C(60)(OH)(24) caused not only concentration (0-0.25 mM)- and time (0-3 hr)-dependent cell death accompanied by the formation of cell blebs, loss of cellular ATP, reduced glutathione (GSH), and protein thiol levels, but also the accumulation of glutathione disulfide and malondialdehyde, indicating lipid peroxidation. Of the other analogues examined, the cytotoxic effects of C(60)(OH)(12) and fullerene C(60) at a concentration of 0.125 mM were less than those of C(60)(OH)(24). The loss of mitochondrial membrane potential and generation of oxygen radical species in hepatocytes incubated with C(60)(OH)(24) were greater than those with C(60)(OH)(12) and fullerene C(60). In the oxygen consumption of mitochondria isolated from rat liver, the ratios of state-3/state-4 respiration were more markedly decreased by C(60)(OH)(24) and C(60)(OH)(12) compared with C(60). In addition, C(60)(OH)(24) and C(60)(OH)(12) resulted in the induction of the mitochondrial permeability transition (MPT), and the effects of C(60)(OH)(12) were less than those of C(60)(OH)(24). Taken collectively, these results indicate that (a) mitochondria are target organelles for fullerenols, which elicit cytotoxicity through mitochondrial failure related to the induction of the MPT, mitochondrial depolarization, and inhibition of ATP synthesis in the early stage and subsequently oxidation of GSH and protein thiols, and lipid peroxidation through oxidative stress at a

later stage; and (b) the toxic effects of fullerenols may depend on the number of hydroxyl groups participating in fullerene in rat hepatocytes. /Fullerenols/
Abstract: PubMed

Nakagawa Y et al; Arch Toxicol. 85 (11): 1429-40 (2011)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Using the rat glioma cell line C6 and the human glioma cell line U251 ... the multiple mechanisms underlying the in vitro anticancer effects of the C(60) fullerene water suspension /are demonstrated/. ... Nano-C(60) in a dose-dependent manner reduced the tumor cell numbers after 24 hr of incubation. The observed antiglioma action of nC(60) at high concentration (1 ug/mL) was due to a reactive oxygen species-mediated necrotic cell damage that was partly dependent on oxidative stress-induced activation of extracellular signal-regulated kinase (ERK). On the other hand, low-dose nC(60) (0.25 ug/mL) did not induce either necrotic or apoptotic cell death, but caused oxidative stress/ERK-independent cell cycle block in G(2)/M phase and subsequent inhibition of tumor cell proliferation. Treatment with either high-dose or low-dose nC(60) caused the appearance of acidified intracytoplasmic vesicles indicative of autophagy, but only the antiglioma effect of low-dose nC(60) was significantly attenuated by inhibiting autophagy with bafilomycin A1. Importantly, primary rat astrocytes were less sensitive than their transformed counterparts to a cytostatic action of low-dose nC(60). These data provide grounds for further development of nC(60) as an anticancer agent.
Abstract: PubMed

Harhaji L et al; Eu J Pharmacol 568 (1-3): 89-98 (2007)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ ... The anti-angiogenic effects of various carbon materials such as graphite, multiwalled carbon nanotubes and fullerenes in vascular endothelial growth factor (VEGF) and basic fibroblast growth factor (FGF2)-induced angiogenesis evaluated in the chick chorioallantoic membrane (CAM) model. All the carbon materials tested showed substantial anti-angiogenic activity against either FGF2- or VEGF-induced angiogenesis in the CAM model. Those carbon materials did not have any significant effects on basal angiogenesis in the absence of the added growth factors.[Murugesan S et al; FEBS Lett 581 (6): 1157-60 (2007)] Full text: PMC1994254
Abstract: PubMed

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ The cytotoxicity of fullerene C60 particles on two mammalian cell lines, ie, the Chinese hamster ovary (CHO) cells and the Madin-Darby canine kidney (MDCK) cells, has been investigated. ... Results ...show that once the concentration of the fullerene aggregates reaches a certain level, the cells start to die. The lethal dosage LD50, which is defined as the lowest fullerene concentration that results in a 50% cell death within 24 hr, has been determined. Furthermore, the percentage of cell mortality increased with increasing fullerene concentration and incubation time yielding a negative effect on cell viability. These results, illustrated by atomic force microscopy (AFM), dynamic light scattering (DLS) and other microscopic techniques, will help to better understand the side effects of fullerene particles in mammalian cells.
Abstract: PubMed

Han B, Karim MN; Scanning 30 (2): 213-20 (2008)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ ...The effects of engineered and combustion-derived carbon nanoparticles on human platelet aggregation in vitro and rat vascular thrombosis in vivo /were studied/. Multiplewall (MWNT), singlewall (SWNT) nanotubes, C60 fullerenes (C60CS) and mixed carbon nanoparticles (MCN) (0.2-300 ug/mL) were investigated. Nanoparticles were compared with standard urban particulate matter (SRM1648, average size 1.4 um). Platelet function was studied using lumi aggregometry, phase-contrast, immunofluorescence and transmission electron microscopy, flow cytometry, zymography and pharmacological inhibitors of platelet aggregation. Vascular thrombosis was induced by ferric chloride and the rate of thrombosis was measured, in the presence of carbon particles, with an ultrasonic flow probe. Carbon particles, except C60CS, stimulated platelet aggregation (MCN>or=SWNT>MWNT>SRM1648) and accelerated the rate of vascular thrombosis in rat carotid arteries with a similar rank order of efficacy. All particles resulted in upregulation of GPIIb/IIIa in platelets. In contrast, particles differentially affected the release of platelet granules, as well as the activity of thromboxane-, ADP, matrix metalloproteinase- and protein kinase C-dependent pathways of aggregation. Furthermore, particle-induced aggregation was inhibited by prostacyclin and S-nitroso-glutathione, but not by aspirin. Thus, some carbon nanoparticles and microparticles have the ability to activate platelets and enhance vascular thrombosis....[Radomski Al Br J Pharmacol 146 (6): 882-93 (2005)] Full text: PMC1751219
Abstract: PubMed

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ A cytotoxicity test protocol for single-wall nanotubes (SWNTs), multi-wall nanotubes (with diameters ranging from 10 to 20 nm, MWNT10), and fullerene (C60) was tested. Profound cytotoxicity of SWNTs was observed in alveolar macrophage (AM) after a 6-hr exposure in vitro. The cytotoxicity increases by as high as approximately 35% when the dosage of SWNTs was increased by 11.30 ug/sq cm. No significant toxicity was observed for C60 up to a dose of 226.00 ug/sq cm. The cytotoxicity apparently follows a sequence order on a mass basis: SWNTs > MWNT10 > quartz > C60. SWNTs significantly

impaired phagocytosis of AM at the low dose of 0.38 ug/sq cm, whereas MWNT10 and C60 induced injury only at the high dose of 3.06 ug/sq cm. The macrophages exposed to SWNTs or MWNT10 of 3.06 ug/sq cm showed characteristic features of necrosis and degeneration. A sign of apoptotic cell death likely existed. Carbon nanomaterials with different geometric structures exhibit quite different cytotoxicity and bioactivity in vitro, although they may not be accurately reflected in the comparative toxicity in vivo. /Single-walled and multi-walled nanotubes/
Abstract: PubMed

Abstract: PubMed

Jia G et al; Environ Sci Technol 39 (5): 1378-83 (2005)

from HSDB

/ALTERNATIVE and IN VITRO TESTS/ Using light microscopy and spectrophotometry, it has been shown that ... water-soluble fullerene C60 cause lysis of human and rat erythrocytes. Fullerene C60 ... partly inhibited the activities of membrane-associated phosphofructokinase and cytoplasmic lactate dehydrogenase in erythrocytes. /Water-soluble fullerene C60/

Solomadin IN et al; Biology Bulletin 35 (4): 436-40 (2008)

from HSDB

/IMMUNOTOXICITY/ ...In this study, /investigators/ studied the immunotoxic mechanism and change of gene expression caused by the instillation of C60s. As a result, C60s induced an increase in sub G1 and G1 arrest in BAL cells, an increase in pro-inflammatory cytokines such as IL-1, TNF-alpha, and IL-6, and an increase of Th1 cytokines such as IL-12 and IFN-r in BAL fluid. In addition, IgE reached the maximum at 1 day after treatment in both BAL fluid and the blood, and decreased in a time-dependent manner. Gene expression of the MHC class II (H2-Eb1) molecule was stronger than that of the MHC class I (H2-T23), and an increase in T cell distribution was also observed during the experiment period. Furthermore, cell infiltration and expression of tissue damage related genes in lung tissue were constantly observed during the experiment period. Based on this, C60s may induce inflammatory responses in the lung of mice.
Abstract: PubMed

Park EJ et al; Toxicol Appl Pharmacol 244 (2): 226-33 (2010)

from HSDB

/IMMUNOTOXICITY/ Hydroxylated fullerenes act as potent inhibitors of cytochrome P450-dependent monooxygenases, and are reported to be very strong antioxidants quenching reactive oxygen species (ROS) production. Effects of nanosized hydroxylated fullerenes on fish neutrophil function and immune gene transcription was investigated using fathead minnow (Pimephales promelas). Neutrophil function assays were used to determine the effects of fullerene exposure in vitro and in vivo on oxidative burst, degranulation and extracellular trap (NETs) release, and the innate immune gene transcription was determined with quantitative PCR (qPCR). Application of fullerenes (0.2-200 ug/mL(-1)in vitro) caused concentration dependent inhibition of oxidative burst and suppressed the release of NETs and degranulation of primary granules (up to 70, 40, and 50% reduction in activity compared to non-treated control, respectively). Transcription of interleukin 11 and myeloperoxidase genes was significantly increased and transcription of elastase 2 gene was significantly decreased in fish exposed to hydroxylated fullerenes for 48 hr in vivo (12 and 3 fold increase, and 5 fold decrease, respectively). Observed changes in gene transcription and neutrophil function indicate potential for hydroxylated fullerenes to interfere with the evolutionary conserved innate immune system responses and encourages the use of fish models in studies of nanoparticle immunotoxicity. /Hydroxylated fullerenes/
Abstract: PubMed

Jovanovic B et al; Aquat Toxicol 101 (2): 474-82 (2011)

from HSDB

/IMMUNOTOXICITY/ ... In the present study, mice received fullerenes intratracheally and were sacrificed at days 1, 6 and 42. Mice that received fullerenes exhibited increased proliferation of splenocytes and increased splenic production of IL-2 and TNF-alpha. Changes in the spleen in response to fullerene treatment occurred at different time-points than in the lung tissue. Furthermore, fullerenes induced CDK2 expression and activated NF-alphaB and NFAT in splenocytes at 6 days post-administration. Finally, CD11b(+) cells were demonstrated to function as responder cells to fullerene administration in the splenic inflammatory process. Taken together, in addition to the effects on pulmonary responses, fullerenes also modulate the immune system.
Abstract: PubMed

Ding N et al; J Hazard Mater 194: 324-30 (2011)

from HSDB

/OTHER TOXICITY INFORMATION/ The use of C(60) fullerenes is expected to increase in various industrial fields. Little is known about the potential toxicological mechanism of action of water-soluble C(60) fullerenes. In our previous research, gene expression profiling of the rat lung was performed after whole-body inhalation exposure to C(60) fullerenes to gain insights into the molecular events. These DNA microarray-based data closely matched the pathological findings that C(60)fullerenes caused no serious adverse pulmonary effects under the inhalation exposure condition. Taking advantage of this, we attempted to characterize time-dependent changes in the gene expression profiles after intratracheal instillation with C(60) fullerenes at different dosages and to identify the candidate expressed genes as potential biomarkers. The hierarchical cluster analysis revealed that the up- or downregulation of genes after intratracheal instillation with 1.0 mg C(60) fullerene particles in rat lung tissue was significantly over-represented in the "response to stimulus" and "response to chemical stimulus" categories of biological processes and in the "extracellular space" category of the cellular component. These results were remarkable for 1 week after the instillation with C(60) fullerenes. In the lung tissues instilled with 1.0 mg C(60) fullerene particles, many representative genes involved in "inflammatory response," such as the Cxcl2, Cxcl6, Orm1, and Spp1 genes, and in "matrix metalloproteinase activity," such as the Mmp7 and Mmp12 genes, were upregulated for over 6 months. The expression levels of 89 and 21 genes were positively correlated with the C(60) fullerene dose at 1 week and 6 months after the instillation, respectively. Most of them were involved in "inflammatory response", and the Ccl17, Ctsk, Cxcl2, Cxcl6, Lcn6, Orm1, Rnase9, Slc26a4, Spp1, Mmp7, and Mmp12 genes were overlapped. Meanwhile, the expression levels of 16 and 4 genes were negatively correlated with the C(60) fullerene dose at 1 week and 6 months after the instillation, respectively. Microarray-based gene expression profiling suggested that the expression of some genes is correlated with the dose of intratracheally instilled C(60)fullerenes. We propose that these genes are useful for identifying potential biomarkers in acute-phase or persistent responses to C(60)

fullerenes in the lung tissue.
Abstract: PubMed

Fujita K et al; Toxicology 274 (1-3): 34-41 (2010)

from HSDB

/OTHER TOXICITY INFORMATION/ Buckminsterfullerene (C60) can form water suspensions (nC60) that exert toxic effects. While reactive oxygen species (ROS) generation has been implicated as the mechanism for mammalian cytotoxicity, /it is proposed/ that nC60 exerts ROS-independent oxidative stress in bacteria, with evidence of protein oxidation, changes in cell membrane potential, and interruption of cellular respiration. This mechanism requires direct contact between the nanoparticle and the bacterial cell and differs from previously reported nanomaterial antibacterial mechanisms that involve ROS generation (metal oxides) or leaching of toxic elements (nanosilver).
Abstract: PubMed

Lyon D, Alvarez P; Environ Sci Technol 42 (21): 8127-32 (2008)

from HSDB

/OTHER TOXICITY INFORMATION/ ... Available data clearly shows that pristine C60 has no acute or sub-acute toxicity in a large variety of living organisms, from bacteria and fungal to human leukocytes, and also in drosophila, mice, rats and guinea pigs. In contrast to chemically--either covalently or noncovalently--modified fullerenes, some C60 derivatives can be highly toxic. Furthermore, under light exposure, C60 is an efficient singlet oxygen sensitizer. Therefore, if pristine C60 is absolutely nontoxic under dark conditions, this is not the case under UV-Visible irradiation and in the presence of O2 where fullerene solutions can be highly toxic through 1O2 formation...
Abstract: PubMed

Kolosnjan J et al; Adv Exp Med Biol 620: 168-80 (2007)

from HSDB

12.1.5 Ecotoxicity Values

LC50; Species: Daphnia magna (Water flea) age <24 hr juvenile, 2nd to 6th broods; Conditions: freshwater, static; Concentration: 460 ug/L for 48 hr

Lovern SB, Klaper R; Environ Toxicol Chem 25 (4): 1132-7 (2006) Available from, as of December 29, 2008: http://cfpub.epa.gov/ecotox/quick_query.htm

from HSDB

12.2 Ecological Information

12.2.1 Environmental Fate/Exposure Summary

Fullerene naturally occurs in shungite, a green-schist facies metamorphic rock containing 99% carbon. Fullerene's production and use in photovoltaic applications, polymer electronics and other polymer applications, fuel cells, and in lubricants and greases may result in its release to the environment through various waste streams(SRC). If released to air, fullerenes, due to their large surfaces area, may adsorb with other atmospheric contaminants (particulate matter) and this adsorption may have an effect on the physicochemical behaviour in air. C60 fullerene absorbs UV-light strongly in the solar spectrum, but the effect in the atmosphere is not certain at this time. Particulate-phase fullerene may be removed from the air by wet and dry deposition. Nanoparticles can remain airborne over a long period because of their small size and light weight. If released to soil, fullerenes are expected to have no mobility based upon a Koc of 1.26X10+7 determined in a soil sorption study. However, C60 fullerene has a potential to form stable colloidal aggregates in water (often referred to as nC60) which may allow transport in the environment. If released into water, fullerenes are expected to adsorb to suspended solids and sediment based upon the Koc. One environmental compartment computer model has predicted that sediment may be a main reservoir for fullerenes. However, the ability to form stable colloidal suspensions in water may affect deposition rates to river, lake and ocean bottoms and associated fate. nC60 fullerene clusters are phototransformed in sunlight, via reaction with singlet oxygen, with a formation of unidentified water soluble products. Aqueous suspensions-clusters of C60 fullerene (nC60) are reported to be antibacterial to a broad range of bacteria. Occupational exposure to fullerenes may occur through inhalation of dust and dermal contact with this compound at workplaces where fullerenes are produced or used. The general population may be exposed through ingestion of medicines or food supplements that contain fullerenes. (SRC)

from HSDB

12.2.2 Natural Occurring Sources

Fullerene was first discovered in shungite, a green-schist facies metamorphic rock containing 99% carbon(1).
Abstract: PubMed

(1) Utsunomiya S et al; Environ Sci Technol 36: 4943-7 (2002)

from HSDB

12.2.3 Artificial Sources

Fullerene's production and use in photovoltaic applications, polymer electronics and other polymer applications,

fuel cells, and in lubricants and greases(1) may result in its release to the environment through various waste streams(SRC).

(1) Cadek M et al; Carbon, 7. Fullerenes and Carbon Nanomaterials. Ullmann's Encyclopedia of Industrial Chemistry 7th ed. (1999-2013). New York, NY: John Wiley & Sons. Online Posting Date: 15 Jan 2010

from HSDB

12.2.4 Environmental Fate

TERRESTRIAL FATE: Based on a classification scheme(1), a Koc value of 1.26X10+7, derived from a soil sorption study(2), indicates that fullerene is expected to be immobile in soil(SRC). However, C60 fullerene has a potential to form stable colloidal aggregates in water (often referred to as nC60) which may allow transport in the environment(3). nC60 Fullerene clusters are susceptible to phototransformation in sunlight(4,5); therefore, photodegradation may be an important fate process on soil surfaces exposed to sunlight(SRC). Aqueous suspensions-clusters of C60 fullerene (nC60) are reported to be antibacterial to a broad range of bacteria(6).

(1) Swann RL et al; Res Rev 85: 17-28 (1983) (2) Chen CY, Jafvert CT; Environ Sci Technol 43: 7370-7375 (2009) (3) Zhang B et al; Environ Sci Technol 43: 9124-9129 (2009) (4) Hou WC, Jafvert CT; Environ Sci Technol 43: 5257-5262 (2009) (5) Hou WC, Jafvert CT; Environ Sci Technol 43: 362-367 (2009) (6) Klaine SJ et al; Environ Toxicol Chem 27: 1825-1851 (2008)

from HSDB

AQUATIC FATE: Based on a classification scheme(1), a Koc value of 1.26X10+7, derived from a soil sorption study(2), indicates that fullerenes are expected to adsorb to suspended solids and sediment(SRC). An environmental compartment computer model has predicted that the concentration of fullerenes in surface waters (US and Europe) might range from 0.003 to 0.018 ug/L while the concentration in sediment would range from 1.05 to 17.1 mg/kg(3). Therefore, sediment may be a main reservoir for fullerenes. However, C60 fullerene has a potential to form stable colloidal aggregate suspensions in water (often referred to as nC60)(4). Although stable suspensions in water may take weeks or months to form, the presence of normal organic matter in natural water and sunlight can greatly enhance the dispersion rate(5). C60 Fullerene is an efficient photosensitizer for singlet oxygen formation in water(6). In aqueous solutions exposed to irradiation in the solar spectrum, C60 clusters (nC60) were phototransformed, via reaction with singlet oxygen, with formation of unidentified water soluble products(6). When exposed to sunlight or UV-light >300nm, the brown to yellow color of nC60 was lost gradually, and the nC60 cluster size decreased with time(7); nC60 phototransformation half-lives were 19 to 41 hours depending of cluster size(7). Aqueous suspensions-clusters of C60 fullerene (nC60) are reported to be antibacterial to a broad range of bacteria(8).

(1) Swann RL et al; Res Rev 85: 17-28 (1983) (2) Chen CY, Jafvert CT; Environ Sci Technol 43: 7370-7375 (2009) (3) Gottschalk F et al; Environ Sci Technol 43: 9216-9222 (2009) (4) Zhang B et al; Environ Sci Technol 43: 9124-9129 (2009) (5) Li Q et al; Environ Sci Technol 43: 3574-3579 (2009) (6) Hou WC, Jafvert CT; Environ Sci Technol 43: 5257-5262 (2009) (7) Hou WC, Jafvert CT; Environ Sci Technol 43: 362-367 (2009) (8) Klaine SJ et al; Environ Toxicol Chem 27: 1825-1851 (2008)

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ATMOSPHERIC FATE: Due to their large surface areas, fullerenes may adsorb with other atmospheric contaminants (particulate matter) and this adsorption may have an effect on the physicochemical behaviour in air(SRC). C60 fullerene absorbs uv-light strongly in the solar spectrum(1), but the effect in the atmosphere is not certain at this time(SRC). Nanoparticles can remain airborne over a long period because of their small size and light weight(2). Particulate-phase fullerenes may be removed from the air by wet and dry deposition(SRC).

(1) Hou WC, Jafvert CT; Environ Sci Technol 43: 5257-5262 (2009) (2) United Nations; Geo Year Book 2007. Emerging Challenges. Nanotechnology and the environment. Available from, as of May 8, 2013: http://www.unep.org/yearbook/2007/PDF/7_Emerging_Challenges72dpi.pdf

from HSDB

12.2.5 Biodegredation

Fullerene C60 spontaneously forms a stable aggregate upon contact with water. Prokaryotic exposure to nano-60 is inhibitory at low concentrations as suggested by lack of growth and decreased aerobic respiration(1). These water suspensions that have been shown to exert toxic effects on bacteria of protein oxidation, changes in cell membrane potential, and interruption of cellular respiration(2). Aqueous suspensions-clusters of C60 fullerene (nC60) are reported to be antibacterial to a broad range of bacteria(3). No data are available to indicate that fullerenes biodegrade(SRC).

(1) Fortner JD et al; Environ Sci Technol 39: 4307-16 (2005) (2) Lyon DY, Alvarez PJJ; Environ Sci Technol 42: 8127-32 (2008) (3) Klaine SJ et al; Environ Toxicol Chem 27: 1825-1851 (2008)

from HSDB

12.2.6 Abiotic Degredation

Fullerenes have been shown to be stable against photodissociation and thermal degradation as it occurs in small amounts mixed with black carbon. Thus fullerene formed by the combustion of coal is preserved in aerosol samples(1). However it has also been suggested that fullerenes are unstable in air. The oxidative degradation, which is UV catalyzed, leads within a few days to the formation of C120 oxides. Ozonolysis of fullerenes leads to the formation of various oxides(2).

(1) Utsunomiya S et al; Environ Sci Technol 36: 4943-7 (2002) (2) Taylor R; Fullerenes. Kirk-Othmer Encyclopedia of Chemical Technology. (2001). New York, NY: John Wiley & Sons. Online Posting Date: 20 Sept 2002.

from HSDB

Fullerene C60 spontaneously forms a stable aggregate upon contact with water which alters substantially the reactivity, color and hydrophobicity of individual C60(1). UV photosensitization of colloidal aggregates of C60 in water resulted in oxygen and superoxide generation by fullerol (hydroxylated C60) suspensions; neither was detected in the nC60 aqueous suspensions, which exhibits a more dense structure(2).

(1) Fortner JD et al; Environ Sci Technol 39: 4307-16 (2005) (2) Hotze EM et al; Environ Sci Technol 42: 4175-80 (2008)

from HSDB

C60 Fullerene is an efficient photosensitizer for singlet oxygen formation in water with a high quantum yield(1). In aqueous solutions exposed to irradiation in the solar spectrum, C60 clusters (nC60) were phototransformed, via reaction with singlet oxygen, with formation of unidentified water soluble products(1). When exposed to sunlight or UV-light >300nm, the brown to yellow color of nC60 was lost gradually, and the nC60 cluster size decreased with time(2); nC60 phototransformation half-lives were 19 to 41 hours depending of cluster size(2).

(1) Hou WC, Jafvert CT; Environ Sci Technol 43: 5257-5262 (2009) (2) Hou WC, Jafvert CT; Environ Sci Technol 43: 362-367 (2009)

from HSDB

12.2.7 Bioconcentration

Based on a measured log Kow of 6.67(1) and lipid fraction contents, the log BCF values of C60 fullerene in cod fish (Gadus sp), salmon (Salmo sp) and earthworms (Lumbricus rubellus) have been estimated to be 4.51, 5.71 and 5.35 respectively(1); these correspond to BCF values of 32360, 512860 and 223870(SRC). According to a classification scheme(2), these BCF values suggest bioconcentration in aquatic organisms is very high(SRC), provided the compound is not metabolized by the organism(SRC).

(1) Jafvert CT, Kulkarni PP; Environ Sci Technol 42: 5945-5950 (2008) (2) Franke C et al; Chemosphere 29: 1501-14 (1994

from HSDB

12.2.8 Soil Adsorption/Mobility

The mobility and transport of fullerenes in aquatic environments are highly dependent on their aggregation and deposition behavior. Naturally occurring particles and surfaces are ubiquitous and therefore interactions of fullerene particles with suspended solids and sediments are more likely to occur than fullerene-fullerene interactions. Natural organic matter readily absorbs to solid surfaces and nanoparticles in aquatic systems. However, the presence of humic acid reduces the aggregation kinetics of fullerene nanoparticles due to steric repulsion induced by the humic acid macrocolecules adsorbed onto the nanoparticle surfaces(1).
Abstract: PubMed

(1) Chen KL, Elimelech M; Environ Sci Technol 42: 7607-14 (2008)

from HSDB

Soil sorption studies using 8 different soils and C60 fullerene in water-ethanol mixtures, determined a log Koc value of 7.1(1) which corresponds to value 1.26X10+7. According to a classification scheme(2), this Koc value suggests that fullerene is expected to be immobile in soil. However, C60 fullerene has a potential to form stable colloidal aggregates in water (often referred to as nC60) which allow facile transport in the environment(3); nC60 was found to readily translocate into nonionic surfactant micelles(3).

(1) Chen CY, Jafvert CT; Environ Sci Technol 43: 7370-7375 (2009) (2) Swann RL et al; Res Rev 85: 17-28 (1983) (3) Zhang B et al; Environ Sci Technol 43: 9124-9129 (2009)

from HSDB

12.2.9 Effluents Concentrations

Fullerenes have been found in particulate matter emitted from coal-fired power plants(1).
Abstract: PubMed

(1) Utsunomiya S et al; Environ Sci Technol 36: 4943-7 (2002)

from HSDB

12.2.10 Probable Routes of Human Exposure

Occupational exposure to fullerenes may occur through inhalation of dust and dermal contact with this compound at workplaces where fullerenes are produced or used. The general population may be exposed through ingestion of medicines or food supplements that contain fullerenes(1).

(1) Nano-C Inc; Fullerene Applications. Available from, as of May 8, 2013: http://www.nano-c.com/fullereneapp.html

from HSDB

13 Literature

13.1 Depositor Provided PubMed Citations

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13.2 NLM Curated PubMed Citations

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13.3 Springer Nature References

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from Springer Nature

13.4 Thieme References

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from Thieme Chemistry

13.5 Chemical Co-Occurrences in Literature

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from PubChem

13.6 Chemical-Disease Co-Occurrences in Literature

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from PubChem

13.7 Chemical-Gene Co-Occurrences in Literature

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View More Chemical-Gene Co-Occurrences and Evidence for Fullerene C60

from PubChem

14 Patents

14.1 Depositor-Supplied Patent Identifiers

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15 Biomolecular Interactions and Pathways

15.1 Protein Bound 3-D Structures

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from PubChem

16 Biological Test Results

16.1 BioAssay Results

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17 Classification

17.1 Ontologies

17.1.1 MeSH Tree

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17.1.2 ChEBI Ontology

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17.1.3 WIPO IPC

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17.1.4 ChemIDplus

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18 Information Sources

1. ChEBI /source/ChEBI
   C60 fullerene
   http://www.ebi.ac.uk/chebi/searchId.do?chebiId=CHEBI:33128 http://www.ebi.ac.uk/chebi/searchId.do?chebiId=CHEBI:33128
   ChEBI Ontology
   http://www.ebi.ac.uk/chebi/userManualForward.do#ChEBI%20Ontology
   http://www.ebi.ac.uk/chebi/userManualForward.do#ChEBI%20Ontology
2. ChemIDplus /source/ChemIDplus
   Buckminsterfullerene
   https://chem.nlm.nih.gov/chemidplus/sid/0099685968 https://chem.nlm.nih.gov/chemidplus/sid/0099685968
   ChemIDplus Chemical Information Classification
   https://chem.sis.nlm.nih.gov/chemidplus/ https://chem.sis.nlm.nih.gov/chemidplus/
3. European Chemicals Agency (ECHA) /source/European Chemicals Agency (ECHA)
   (C60-Ih)[5,6]fullerene
   https://echa.europa.eu/information-on-chemicals/cl-inventory-database/-/discli/details/161572
   https://echa.europa.eu/information-on-chemicals/cl-inventory-database/-/discli/details/161572
4. FDA/SPL Indexing Data /source/FDA/SPL Indexing Data
   NP9U26B839
   https://www.fda.gov/ForIndustry/DataStandards/SubstanceRegistrationSystem-UniqueIngredientIdentifierUNII/
   https://www.fda.gov/ForIndustry/DataStandards/SubstanceRegistrationSystem-UniqueIngredientIdentifierUNII/

5. HSDB /source/HSDB

   FULLERENES
   https://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@rn+@rel+NO CAS RN
   https://toxnet.nlm.nih.gov/cgi-bin/sis/search/r?dbs+hsdb:@term+@rn+@rel+NO CAS RN

6. MassBank of North America (MoNA) /source/MassBank of North America (MoNA)

   C60
   http://mona.fiehnlab.ucdavis.edu/spectra/browse?inchikey=XMWRBQBLMFGWIX-UHFFFAOYSA-N
   http://mona.fiehnlab.ucdavis.edu/spectra/browse?inchikey=XMWRBQBLMFGWIX-UHFFFAOYSA-N

7. NIST /source/NIST

   Buckminsterfullerene
   http://www.nist.gov/srd/nist1a.cfm http://www.nist.gov/srd/nist1a.cfm

8. PDB /source/PDB

   The Protein Data Bank (PDB) is a crystallographic database for the three-dimensional structural data of large biological molecules, such as proteins and nucleic acids
   http://www.rcsb.org/ligand/60C http://www.rcsb.org/ligand/60C

9. Springer Nature /source/Springer Nature

   Literature references related to scientific contents from Springer Nature journals and books. Read more ...
   https://link.springer.com/

10. Thieme Chemistry /source/Thieme Chemistry

    Literature references related to scientific contents from Thieme journals and books. Read more: http://www.thieme-chemistry.com

11. Wikipedia /source/Wikipedia

    buckminsterfullerene
    https://en.wikipedia.org/wiki/Buckminsterfullerene https://en.wikipedia.org/wiki/Buckminsterfullerene

12. PubChem

    Data deposited in or computed by PubChem
    https://pubchem.ncbi.nlm.nih.gov https://pubchem.ncbi.nlm.nih.gov

13. MeSH /source/MeSH

    Fullerenes
    https://www.ncbi.nlm.nih.gov/mesh/68037741 https://www.ncbi.nlm.nih.gov/mesh/68037741
    MeSH Tree
    http://www.nlm.nih.gov/mesh/meshhome.html http://www.nlm.nih.gov/mesh/meshhome.html

14. WIPO /source/WIPO

    International Patent Classification
    http://www.wipo.int/classifications/ipc/ http://www.wipo.int/classifications/ipc/