Fullerene nanoparticles in soil: Analysis, occurrence and fate

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Citation for published version (APA):
List of papers used in this thesis

Sample collection: A. Carboni
Standard preparation: A. Carboni, E. Emke
LC-UV/FLU analysis: A. Carboni
Writing: A. Carboni
Supervision and reviewing: J.R. Parsons, K. Kalbitz, P. de Voogt

Sample collection: A. Carboni
Standard preparation: A. Carboni
LC-MS analysis: A. Carboni, R. Helmus
Writing: A. Carboni
Supervision and reviewing: J.R. Parsons, K. Kalbitz, P. de Voogt

III. Carboni A., Helmus R., Emke E., van den Brink N., Parsons J.R., Kalbitz K., de Voogt P. Analysis of fullerenes in soils samples collected in The Netherlands (Environmental Pollution, in revision)
Sample collection: A. Carboni, N. van den Brink, E. Emke
Standard preparation: A. Carboni, E. Emke
LC-MS analysis: A. Carboni, R. Helmus
Writing: A. Carboni
Supervision and reviewing: J.R. Parsons, N. van den Brink, K. Kalbitz, P. de Voogt

IV. Carboni A., Helmus R., Parsons J. R., Kalbitz K., de Voogt P. Incubation of solid state C60 fullerene under environmentally relevant conditions (submitted to Chemosphere)
Experiments: A. Carboni
LC-MS analysis: A. Carboni, R. Helmus
Writing: A. Carboni
Supervision and reviewing: J.R. Parsons, K. Kalbitz, P. de Voogt
Curiosities

Fullerenes were named in homage to Sir Richard Buckminster Fuller (1895 – 1983), the inventor of the geodesic domes which resemble these molecules. For this C\textsubscript{60} is commonly named Buckminsterfullerene or even Buckyball. Sir Fuller was likely among the most interesting personalities of the last century and one of the first concerned about sustainability and human survival under the existing socio-economic system (yet he was optimistic about the future of humans). In addition to being an architect, systems theorist, designer and inventor (28 patents) Sir Fuller was also an excellent writer (he published more than 30 books) and author of some amazing quotes like the one at the beginning of this book. My absolute favourite is:

“When I am working on a problem, I never think about beauty but when I have finished, if the solution is not beautiful, I know it is wrong.”

R. Buckminster Fuller

The size ratio between fullerenes (C\textsubscript{60}) and a soccer ball is similar to that between a soccer ball and the planet Earth.

Fullerenes are the most symmetric molecules in the world. There are 120 symmetry operations, like rotations around an axis or reflections in a plane, which map the molecule onto itself. This makes C\textsubscript{60} the molecule with the largest number of symmetry operations.
Like many other interesting things, the discovery of fullerenes happened by chance. It seems that the first 3d structure was obtained by the authors while playing with paper hexagons and pentagons, basically an origami.

The discovery of fullerenes (in 1985), a new allotrope of carbon out of the blue, was quite an event the scientific community and the discoverers will receive a Nobel Prize for it (in 1996). However, at that time the possible applications and consequences for humans were still unknown and argument of debate. Shortly after the discovery a member of the British House of Lords remarkably commented “It (C\textsubscript{60}) does nothing in particular and does it very well”.

Considering that it was published on Nature, was cited some thousands times, it won a Nobel prize and basically started a new entire field of research, the first publication about fullerenes was pretty amazing. The title is short and sweet (‘C\textsubscript{60}:Buckminsterfullerene’), the paper runs to less than two pages, there is a photograph of a soccer ball but no supplementary information, and in places the text is written in an informal style that is hard to imagine appearing in a journal today.

Even though C\textsubscript{60} is relatively soft under normal conditions it can be compressed at 320 000 atmospheric pressure to create a substance so hard it can dent a diamond (it could be the hardest material on Earth).

When a molecule of C\textsubscript{60} is attached to twelve molecules of nitrous oxide, the resulting structure can explode in a controlled reaction. Surprisingly, the main application of this “Buckybomb” could be medical.

According to the rules for making icosahedron, an infinite number of (always larger) fullerenes can exist. The smallest is a C\textsubscript{20} (actually the smallest is a C\textsubscript{28}...C\textsubscript{20} is unstable). In addition, you also get “Buckyonions”,

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i.e. multi-layered round carbon particles where fullerenes are one into the other like an onion peel.

The solubility of fullerenes in certain solvents is weird and maxed at room temperature. It’s something like putting sugar in your hot tea and see it dissolving while the tea cools down.

There’s a rock (actually a mineraloid) relatively rich in fullerenes. It’s called Shungite, has a 98 weight percent of carbon, it’s very black, relatively rare and mostly found in Russia.

Fullerenes are also weird to work with in the lab. When dissolved into solvents (which is something I did on a daily basis while working at the experiments in this thesis) different molecules gives different colours in different solvents. For instance, $C_{60}$ is violet in toluene and yellow in water. $C_{70}$ instead is dark red in toluene and pink into water.

About nanoparticles in general, nanotechnology is the (recent) ability to manipulate matter at the nano size. However, ancient populations have used nanoparticles since thousands years ago, e.g. introducing them into utensils in order to produce a glittering effect.

Nanoparticles sounds small but they are not that small. For instance, they are much bigger that most of the other stuff you breath in the traffic (oxygen, methane, NOXs, benzene, PAHs). However, for being particles, they are absolutely small.

Nanoparticle can actually be pretty big. This is due to the current terminology that defines nanoparticles to be so if they are very small (less than 100 nm) in at least one dimension. This means that a nano-wire could be very thin but also very very long. For the same reason, a nano-sheet could be 1 nm thick but have a surface large enough to wrap the planet. However, this is not likely to happen.
Acknowledgements

First, my deepest gratitude for my supervisors and promotors, Pim de Voogt, Karsten Kalbitz and John R. Parsons for supporting my research and trusting me and my ideas.

I gratefully acknowledge the Dutch government and the NanoNextNL project which supported and funded my doctoral work.

I am thankful and grateful to all my colleagues that participated, inspired and helped this project. Most especially Chiara Cerli, Joke Westerveld, Rick Helmus Leo Hoitinga and Peter Serne at the UvA and Erik Emke, Annemarie Kolkman and Patrick Bauerlein at the KWR.

Many thanks to my colleagues and friends Vittorio, Manuel, Christian and Sebastian whom I can always rely on and who have been travel companions.

Many thanks also to the NanoNextNL and NanoSENSE colleagues, it was wonderful to work with you.

The deepest thanks are to my family and loved ones, my partner Cinzia and my son Leonardo.
Notes