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Chemobronics database

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Supporting information for this article is given via a link at the end of the document.

Abstract: Given the growing importance of the field of chemobronics since the term was coined in 2015 and the increase in the number of published papers, it has become necessary to catalogue all the papers published to date. Here we present the chemobronics database, which lists all the chemical gardens synthesised according to their anion, cation and experimental protocol. The aim of this database is to encourage the study and dissemination of chemical gardens in order to find new experimental avenues in the field of chemobronics. As this is such a fruitful field, the database is continuously updated.

Introduction

Chemical gardens are self-organizing structures that biomimic plant-like structures with tubes and vesicles shapes. Johann Glauber described these structures for the first time in 1646.^[1] Since then, chemical gardens have attracted the attention of scientists, who have recently called this research field chemobronics.^[2] Chemobronics can be used to study a number of subjects among which are corrosion, sensors and electrochemistry, just to name a few.^[2–5] Chemobronics can help answer the most longstanding scientific question, i.e., how did life originate, given that life could have originated in oceanic hydrothermal vents, which are natural chemical gardens.^[2,6–11]

Classical experiments on chemical gardens were performed by adding to a solution of an anion a metal salt (except the too-soluble alkali metals). The metal salt can be added in solid form, as single crystal or as a pellet of polycrystalline powder, or as a second liquid. The most common anion solution used to promote the growth of chemical gardens have been silicate, but many others have also been used.^[2] In the case of metals, a large number of them have been used, e.g., Ca, Mg, Fe, Ba, Cu...^[2] In addition to what the classical experiments describe, other kinds of experiments have been conducted to promote the growth of chemical gardens, e.g., using gel or paste,^[12–14] by corrosion,^[3,15] by performing electrochemical experiments^[5] or carrying out experiments in confined geometries.^[9,16–18]

Therefore, taking into account the wide number of conditions to promote the growth of chemical gardens, here we present the chemobronics database, which curates all the papers published to date about chemical gardens, to the best of our knowledge. This database is intended to be a tool for all researchers in the field of chemobronics, where they can search for all synthesized chemical gardens and to open up new avenues of research in the field of chemobronics.^{[19][20]}

Results and Discussion

Since the term chemobronics was coined in 2015, the number of publications in this field has increased. From the first description of chemical gardens by Glauber^[1] in the 17th century up to and including 2015, 95 papers have been published. Since then and up to the end of 2022, when this article is written, 104 papers have been published (Fig. 1).[‡] In addition, 2 papers have been already accepted and taken into account in the database (although they are not shown in figure 1).^[21,22] This increase in the number of publications demonstrates the scientific interest in this field, as also testified by the award of a COST project of the European Union (COST Action CA17120 Chemobronics).

Therefore, and in order to help the scientific community, the chemobronics database has been designed. This database can be downloaded from zenodo repository as .csv^[19] or can be consulted live on a dedicated website (Fig. 2).^[20] In this database, the chemical gardens have been catalogued according to the anion and cation used, and the experimental setup. Accompanying this information are the references to the papers describing these chemical gardens. Therefore, in this database, a chemical garden with the same

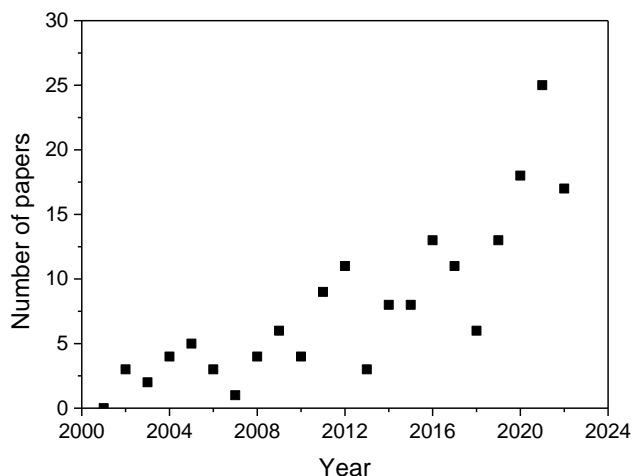


Figure 1: Number of papers (and books) published per year since 2000. Before 2000 only 23 works were published. The two accepted papers that will be published in 2023 are not included in the graph, but are included in the database.

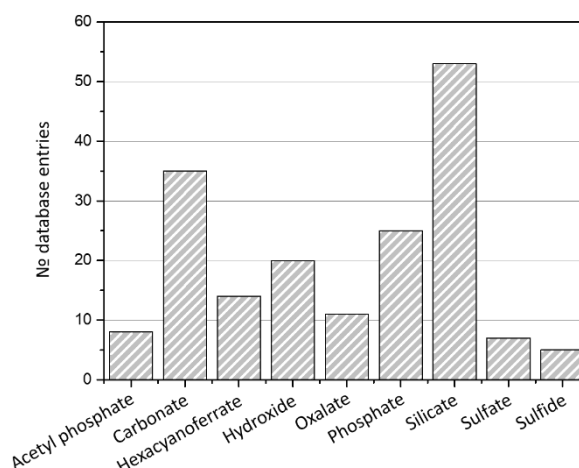


Figure 3. Number of database entries per anion, considering all the anions with more than 5 entries in the database.

anion and cation may appear in several entries if different experimental methods have been used to synthesize it or if it has been combined with an additional ion. For example, the combination of silicate with calcium appears a total of 8 times in the database, as it has been synthesized using three different experimental approaches (solid, gel and paste), but it has also been synthesized by combining them with CO₂, with carbonate anion, with phosphate anion and with iron cation. These calcium silicate gardens have been described in a total of 27 different papers.

Thanks to this database, some interesting results can be extracted on the main chemical gardens on which chemobrionics research has focused. The main anion used has been silicate (53 entries in the database), followed by carbonate (35 entries) and phosphate (25 entries). In figure 3 can be seen all those anions which have more than 5 entries in the database. Among the cations, iron has been the most used cation, both +2 and +3 (32 entries), followed by calcium (31 entries) and copper (21 entries). Focusing on the methods used, using one solid phase (i.e. solid setup in the database) and mixing two liquid phases (i.e. liquid setup) have been by far the most used methods, appearing in 86 and 72 entries, respectively.

Show: entries Search:

Anion	Cation	Setup	Refs
<input type="text" value="All"/>	<input type="text" value="All"/>	<input type="text" value="All"/>	<input type="text" value="All"/>
Alginate	Ca ²⁺	Liquid	Zahorán et al. 2022
Aluminate	Ca ²⁺	Solid	Coatman et al 1980
Arsenate(III)	Cu ²⁺	Solid	Copisarow 1929
Arsenate(III)	Mg ²⁺	Solid	Copisarow 1929
Arsenate(V)	Co ²⁺	Solid	Copisarow 1929
Arsenate(V)	Cu ²⁺	Solid	Copisarow 1929
Borate	Fe ³⁺	Solid	Hazlehurst 1941
Borate	Zn ²⁺	Solid	Alp et al. 2021
Carbonate	Ba ²⁺	Solid	Ibsen et al. 2014 , Copisarow 1929
Carbonate	Ba ²⁺	Liquid	Schusztzer and De Wit 2016 , Getenet et al. 2020

Showing 1 to 10 of 193 entries Previous 2 3 4 5 ... 20 Next

Figure 2: Screenshot of the chemobrionics database. The database is organized in 4 columns: anion, cation, setup and references (refs). In each column there is a search field to search within the column. At the top right, there is a search field to browse the entire database.

In other cases, anions and cations only appear in one entry, so that these routes of synthesis of chemical gardens are open to new experimental contributions. For instance, that is the case of aluminates,^[23] chlorite^[24] or tungstates,^[25] for anions; and lithium,^[17,26] cerium^[27] or gold,^[1,28] for cations.

Within the database, there are chemical gardens that can be considered special, because they cannot be differentiated by anions and cations, so the same terms appear in both fields of the database, such as ice,^[29] steel,^[3,15] Portland cement,^[30] and xenon hydrates.^[31]

It is also interesting to note that some researchers have studied natural structures that they have described as chemical gardens, although such structures are less accessible than the experimental synthesis of chemical gardens and, therefore, there are fewer references. The natural structures were composed of carbonates,^[8,32] oxides,^[6,33] sulfates,^[34] or methane hydrates.^[35]

Conclusion

In conclusion, given the increasing number of works in the field of chemobionics, we have found it necessary to create a database to collect and catalogue them in order to facilitate the bibliographic work of future research. In addition, this database can be used to detect research gaps on which to focus future works. This database is alive and the references cited in it are periodically updated. For this reason, the zenodo repository is used for its distribution, where future updates can be easily found. Future updates of the database can be adapted to the needs of the community by making it more specific as necessary.

Supporting information

A csv file with the complete database can be found as a supplementary information. See DOI: 10.5281/zenodo.6607124

Conflicts of interest

There are no conflicts to declare.

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Keywords: Chemical Gardens • Chemobionics • Inorganic Chemistry

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