

Why Alkali-Activated Materials (AAM) are NOT Geopolymers ? Prof. Dr. Joseph Davidovits, Geopolymer Institute

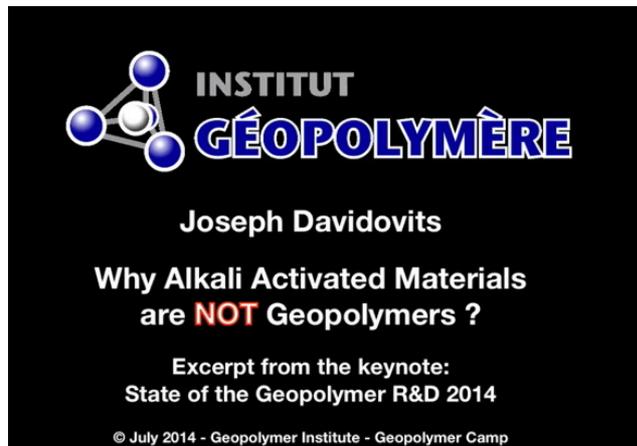
(November 2018, script of the Video series available at the Geopolymer Institute, <https://www.geopolymer.org/faq/alkali-activated-materials-geopolymers/> and on YouTube).

Many scientists and civil engineers are mistaking alkali activation for geopolymers, fueling confusion, using them as synonyms without understanding what they really are.

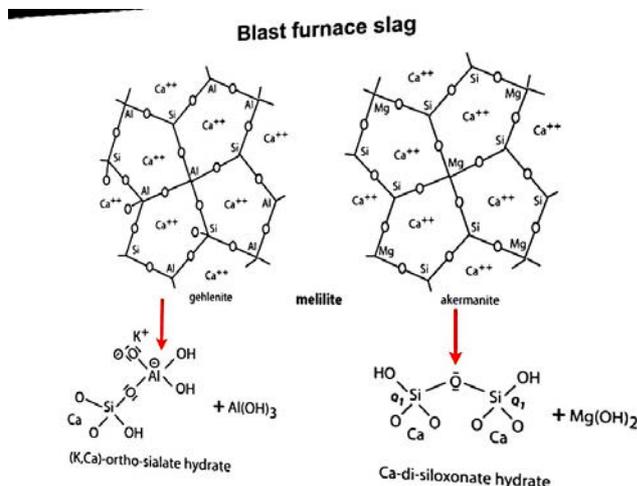
To sum up: Alkali-Activated Materials (AAM) are **NOT Polymers**, so they cannot be called Geopolymers. Geopolymers are **NOT a subset of AAM** because they are not a calcium hydrate alternative (no NASH, no KASH). They belong to two very different and separate chemistry systems (a hydrate/precipitate that is a monomer or a dimer versus a true polymer). Those who claim that both terms are synonyms are promoting a misleading scientific belief. **Learn why by watching these four videos.**

In my four keynotes at the Geopolymer Camp (2014-2017), I explained why Alkali-Activated-Materials are not Geopolymers, or why alkali-activation is not geopolymerization. We have selected all the sequences that had been dedicated to this issue in the GPCamp-2014, 2015, 2016 and 2017 keynotes. These videos are titled: *Why Alkali-Activated Materials are NOT Geopolymers*. You will finally understand why there are two different systems.

Part 1 (2014): AAM are not geopolymers, two different chemistry



I explain the main differences between AAC (Alkali-Activated Concrete), AAS (Alkali-Activated Slag), AAF (Alkali-Activated Fly Ash) and Slag-Metkaolin-based Geopolymer cement, in terms of chemistry, molecular structure, long-term durability. In a second part, on hand of the industrialization of Slag/fly ash-based geopolymer cement/concrete implemented by the company Wagners, Australia, I focus on the results provided by the carbonation testing data obtained for ordinary Portland cement, AAS and EFC (Slag/fly ash-based geopolymer). The tests were carried out at the Royal Melbourne Institute of Technology RMIT in Australia. Geopolymer behaves like regular Portland cement, whereas AAS gets very bad carbonation results.

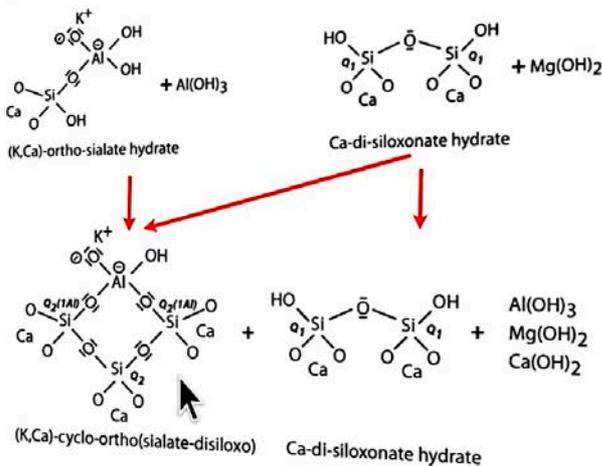


The slag is made out of a glassy substance that is called "melilite" which is a solid solution of gehlenite (Ca-silico-aluminate) and akermanite (Mg-silicate) (see in Fig. 1). When these two minerals are subjected to alkalination (not activation), they depolymerize under the action of the alkali.

Figure 1: first step of slag alkalination.

The gehlenite (on the left) is transformed into (K, Ca)-ortho-sialate-hydrate, a small molecule and precipitation of aluminum hydroxide Al(OH)₃. Akermanite (on the right) undergoes depolymerization into the small molecule Ca-di-silicate-hydrate that is the CSH of the cement chemistry, plus the precipitation of magnesium hydroxide Mg(OH)₂.

The two small molecules will interact (Fig. 2) and form a more complicated structure (on the left), a cycle involving 3 Si, 1 Al, 1 K and 3 Ca, (K, Ca)-cyclo-ortho (sialate-disiloxo), and also CSH Ca-di-siloxonate-hydrate, plus precipitation of $\text{Al}(\text{OH})_3$, $\text{Mg}(\text{OH})_2$ and $\text{Ca}(\text{OH})_2$.

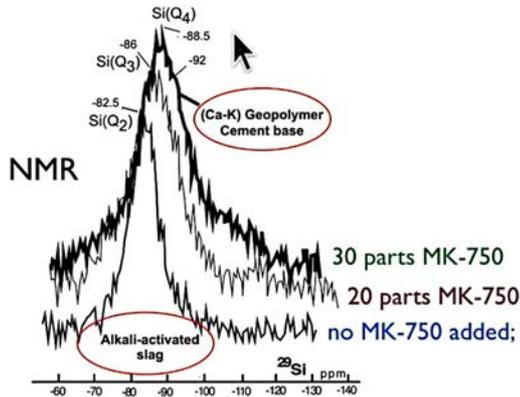


The problem resulting from this reaction is the following one: the alkali cation K^+ is outside of the structure of the cycle; same case for Na^+ . This simply means that the cations will migrate very fast in contact with water. This will generate leachates and bad long-term properties. This is generally what people are getting with AAS. This is not geopolymer and not the end term of geopolymerization.

Figure 2: alkali-activated slag unstable structure.

Therefore, all people who are claiming that alkali-activation of slag is similar to geopolymerization are totally wrong and essentially in a lot of scientific papers. They are only doing this first step of geopolymerization.

From alkali-activated slag to geopolymer cement



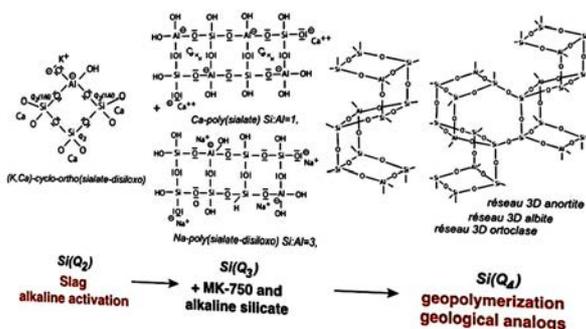
To continue geopolymerization into genuine geopolymer cement, we must add a networking element that will interact with the free cations (K^+ , Na^+). NMR spectroscopy (Fig. 3) shows the ²⁹Si resonance for AAS, with $\text{Si}(\text{Q}_2)$ species. Adding the networking molecule of metakaolin MK-750 we obtain a $\text{Si}(\text{Q}_3)$ branched molecule that is bigger and more stable, and we end up with a $\text{Si}(\text{Q}_4)$ stable specie, a three-dimensional networking.

Figure 3: ²⁹Si NMR spectrum of slag/MK-based geopolymer, evolution from alkali-activated-slag towards geopolymer cement.

The mechanism is summarized in Fig. 4. AAS gets high strength, for example 90 MPa compressive strength, vs “only” 60/70 MPa for slag/MK-based geopolymer. But AAS generates

leachates, and is not long-term stable with poor physico-chemical properties because, in the chemical structure of its hydroxylated oligomer, the Na^+ or K^+ cations are located on the edge of the cyclic oligomer (K, Ca)—cyclo-ortho (sialate-disiloxo) with $\text{Si}(\text{Q}_2)$. They can easily migrate in contact with water and be leached out. This is not the case for geopolymer cement with its three-dimensional networking.

Slag / MK-750-based geopolymer



From alkali-activated slag to stable 3D geopolymer network resulting from the addition of MK-750. From left to right, structural changes from unstable cyclic oligomer $\text{Si}(\text{Q}_2)$ obtained by alkali activation of blast furnace slag, through ribbon bidimensional polymers $\text{Si}(\text{Q}_3)$ towards stable reticulated 3D geopolymers with $\text{Si}(\text{Q}_4)$.

Figure 4: Hardening results from the polycondensation of the ribbon bidimensional polymers Ca—poly (sialate) $\text{Si}:\text{Al}=1$, and (Na, K)—poly (sialate- disiloxo) $\text{Si}:\text{Al}=3$, with $\text{Si}(\text{Q}_3)$ towards more stable reticulated 3D geopolymers with $\text{Si}(\text{Q}_4)$.

This mechanism provides long-term stability because the Na^+ or K^+ cations are fixed and trapped inside the frameworks of the types Ca—anorthite, Na—albite or K—orthoclase (as in natural feldspar or plagioclase). In fact, by varying the ratio slag / MK-750,

end-users can choose between high compressive strength and low stability (danger for alkali-activated slag), or optimal strength with long-term durability and corrosion resistance for geopolymer cements.

Slag-based geopolymer cement **Alkali-activated slag**

↓ ↓

RMIT – Accelerated Carbonation Tests

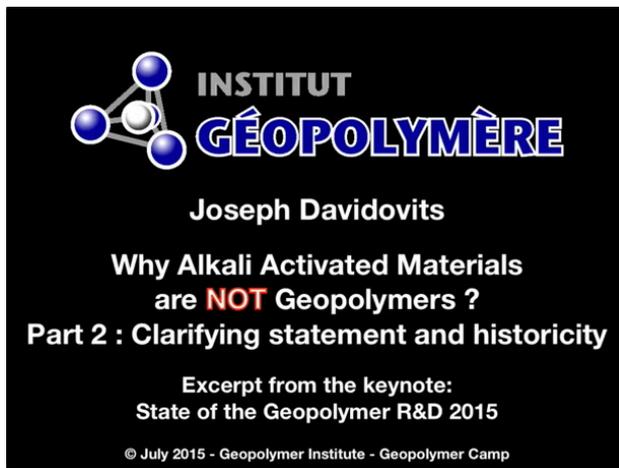
Days	EFC		OPC	30% GGBS	50% GGBS	70% GGBS	AAS
	40 MPa	50 MPa	50 MPa	40 MPa	40 MPa	35 MPa	40 MPa
7	1.78	1.81	1.78	2.04	1.93	2.61	4.91
14	1.63	2.22	1.55	1.71	2.00	2.65	4.38
21	2.31	1.88	1.57	1.81	2.12	2.77	4.47
28	2.12	1.66	1.46	1.72	2.10	2.76	4.46
Average	2.05	1.94	1.59	1.82	2.04	2.70	4.56
Std Dev	0.34	0.23	0.14	0.15	0.09	0.08	0.24

Fly ash plays the same role as metakaolin. This is exemplified in Fig. 5 which compares the carbonation tests of slag-based geopolymer cement (slag/fly ash EFC from Wagners) with OPC plain, OPC with various slag GGBS content and AAS alkali-activated-slag.

Figure 5: accelerated carbonation tests: EFC geopolymer concrete gets 1.94 mm to 2.05 mm CO₂ penetration compared with 4.56 mm for AAS (RMIT testing).

The carbonation tests for geopolymer concrete and slag/blended Portland cement are similar.

Conclusion: AAM is not geopolymer.

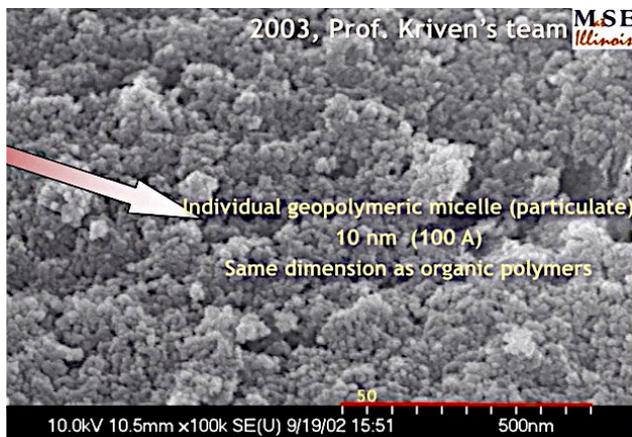


Part 2 (2015): Clarifying statement about all the false ideas and assertions

I made a clarifying statement about all the false ideas and assertions written by several alkali activated materials scientists (incorrectly using the word “geopolymer” for marketing purpose in place of AAM) and blindly imitated by others. I explain why it is a true polymer with a well-known and understood chemistry (as opposed to those who claim it is a “gel” of unknown character), mentions the historicity and discovery of geopolymer chemistry, the real contributions of Glukhovsky and what he really wrote about geopolymers. I develop the range of actual industrial applications that goes far beyond cement made out of wastes.

Got to: <https://www.geopolymer.org/faq/alkali-activated-materials-geopolymers/> and on YouTube.

In this presentation, I focus on the polymeric nature of geopolymer.



A polymer is a macromolecule with definite size and molecular weight. These two key values are established by several complementary physical methods working either in the solid state (electron microscopy) or in solution (light-scattering). A gel, on the other hand, designates an indefinite amorphous compound with unresolved dimensions.

Figure 6: Nano-particulate or geopolymeric micelle, point of the arrow, after Kriven et al.

Kriven *et al.* (2003) used TEM (transmission electron microscopy) to investigate the microstructure of fully reacted potassium-poly(sialate-siloxo) type geopolymers. It consists of nanoparticulates ranging from 5 to 15 nm in

dimensions (50 to 150 Å) separated by nanoporosity, the features of which are of the order of 3 to 10 nm (Fig.6). The nano-particulates represent a characteristic feature of the geopolymer matrix and their dimensions suggest the presence of a macromolecule of definite size, and therefore, definite molecular weight. It is the accumulation of these nanoparticulates, or individual particulates, that forms the

geopolymer matrix. They are sometimes called precipitated particles and their dimensions are similar to those of organic molecules.

The temperature stability of the geopolymer nanoparticulates strongly supports the presence of giant molecules. In other words, it is in favor of the polymeric model.

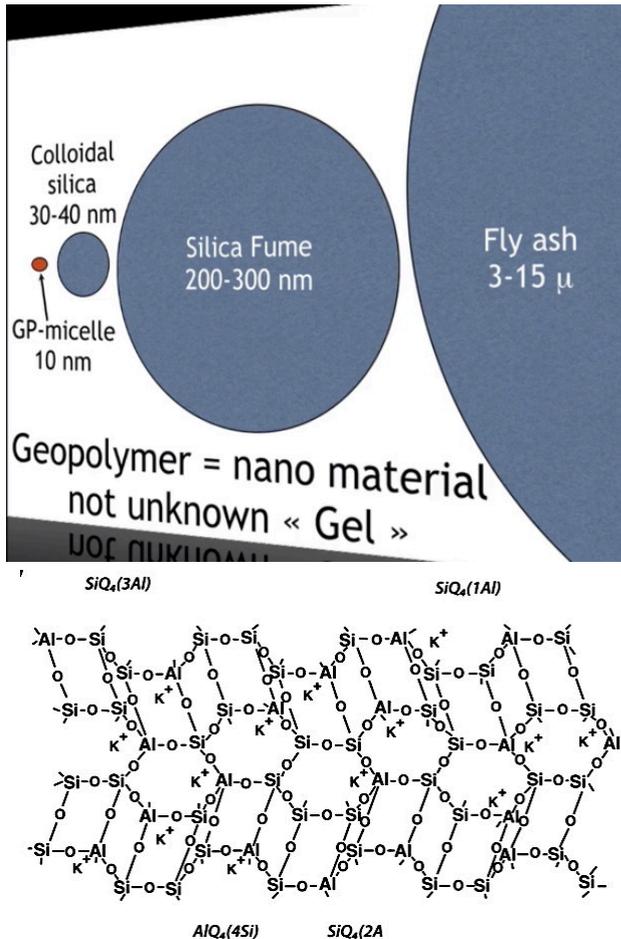


Figure 7: Dimension of the geopolymeric micelle (particulate) compared to colloidal silica, silica fume and fly ash spheres.

Fig. 7 shows the very small dimension of this geopolymer nano-particulate, when compared to other spherical structures, colloidal silica, silica fume and fly ash. The core of these nanoparticulate geopolymers is made of aluminosilicate frameworks that are similar to those of rock-forming minerals.

Yet, there are major differences. In 1994, we simulated a theoretical structure for K- poly (sialate-siloxo) (K)-(Si-O-Al-O-Si-O) that was consistent with the NMR spectra. It is displayed in Fig. 8 and does not show the presence of water in the structure. This is demonstrated by the fact that ²⁷Al MAS—NMR spectroscopy of all (Na, K)-poly (sialate-siloxo) (Na, K)-(Si-O-Al-O-Si-O) showed ²⁷Al chemical shifts in the range of 55 ppm which indicates that the aluminum is of the AlQ₄(4Si) type and is tetrahedrally coordinated, or more exactly tetravalent (see Fig.17 below).

Figure 8: 3D-structural model for fully reacted K—poly (sialate-siloxo), Davidovits (1994)

The absence of any other resonance in the ²⁷Al NMR spectrum and the extremely narrow peak at 55 ppm, excludes any residual singular building units of low molecular weight such as dimers and trimers. (Na, K)-poly (sialate-siloxo) (Na, K)-(Si-O-Al-O-Si-O) are true three-dimensional framework silico-aluminates with polymeric building units.

APPLICATIONS:

The applications are the result of a very precise chemical mechanism involving covalent bonding and promoting the formation and production of ceramic-like materials, **NOT JUST CEMENT and building materials.**

The atomic ratio Si: Al governs the chemical, physical and mechanical properties of ceramic-like materials found in a wide variety of uses. Some geopolymer applications are still in development while others are already industrialized and marketed. The following areas may be mentioned (Fig. 9):

- Si:Al=1: geopolymer ceramics and manufacturing techniques with low-CO₂ greenhouse gas emission;
- Si:Al=2: geopolymer cements and concretes with low-CO₂ greenhouse gas emission and low energy demand; treatment and containment of toxic, radioactive and nuclear waste and mine tailings;
- Si:Al=3: fire- and temperature-resistant compounds for the manufacture of prototypes and tooling;
- Si:Al>3: high-tech geopolymer resins and binders for paints, coatings and grouts resistant to corrosion and temperature; tooling for Aluminum industry;
- Si:Al>20: high-tech composites made of carbon fiber and others, resistant to fire and heat for aeronautics and automotive, for the repair and reinforcement of civil engineering infrastructure.

The wide variety of potential applications includes: fire-resistant materials, decorative stone artifacts, thermal insulation, low-tech building materials, low-energy ceramic tiles, refractory items, thermal shock refractories, biotechnology (materials for medical applications), foundry industry, cement and concretes, composites for infrastructure repair and reinforcement, high-tech composites for aircraft interior and automobiles, high-tech resin systems, radioactive and toxic waste containment, arts and decoration, cultural heritage, archaeology and history of sciences.

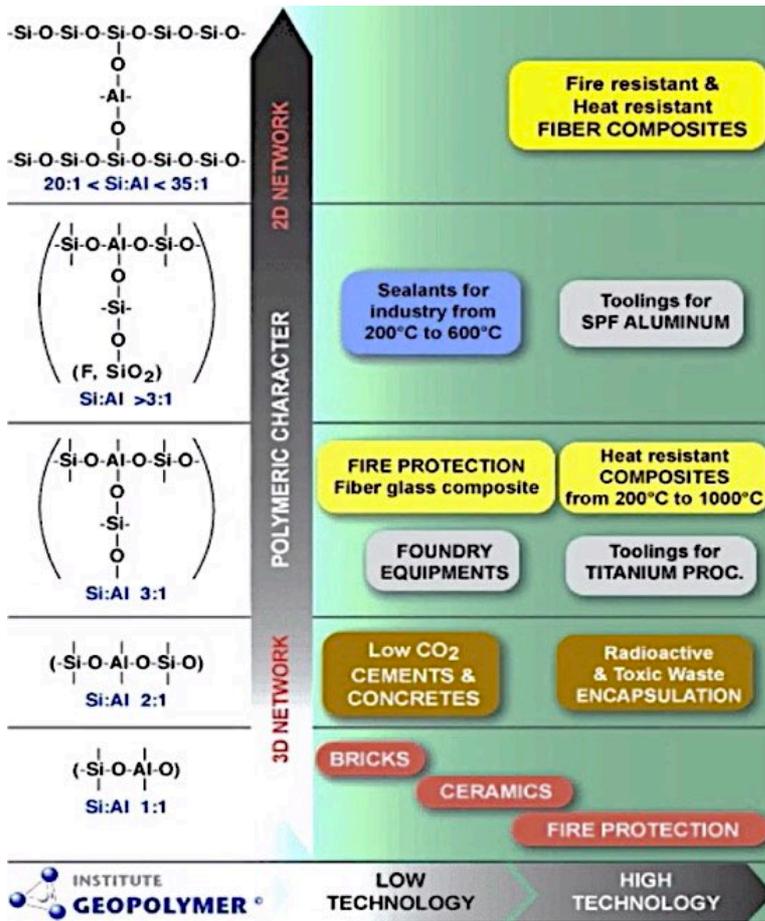


Figure 9: The atomic ratio Si: Al in the poly(sialate) structure determines the properties and application fields. A low Si: Al ratio (1,2,3) initiates a 3D-Network that is very rigid. A high Si: Al ratio, higher than 15, confers linear polymeric character on the geopolymeric material.

To sum up: **GEOPOLYMER** applications are **NOT JUST FOR CEMENT**. **AAM** are only **CONCRETE**. Alkali-activated-material **AAM** is not **GEOPOLYMER**.


**INSTITUT
GÉOPOLYMÈRE**
 Prof. Joseph DAVIDOVITS
 Why Alkali Activated Materials
 are **NOT** Geopolymers ?
 Part 3: What scientists are now writing about this issue
 Excerpt from the keynote:
 State of the Geopolymer R&D 2016
 © July 2016 - Geopolymer Institute - Geopolymer Camp

Part 3: (2016): AAM are not polymers, so they cannot be called “geopolymers”

I emphasize the fact that Alkali Activated Materials (AAM) are not polymers; therefore, they cannot be called “geopolymers”. I present what scientists are now writing about this issue. They now agree with proven facts and that it is a big scientific mistake to think AAM and geopolymer as synonyms, and people shall stop doing so. Geopolymer cement is not a CSH derivative like NASH or KASH; therefore, scientists are now stating that

applying the CSH terminology from Portland cement is not only inappropriate, but also calling them NASH and KASH is totally wrong. Those who purposefully use and propagate these misleading languages delude the understanding of the true chemical reactions that really occur (never a hydrate or a gel, but a polymer), resulting in confused interpretations.

Got to: <https://www.geopolymer.org/faq/alkali-activated-materials-geopolymers/> and on YouTube.

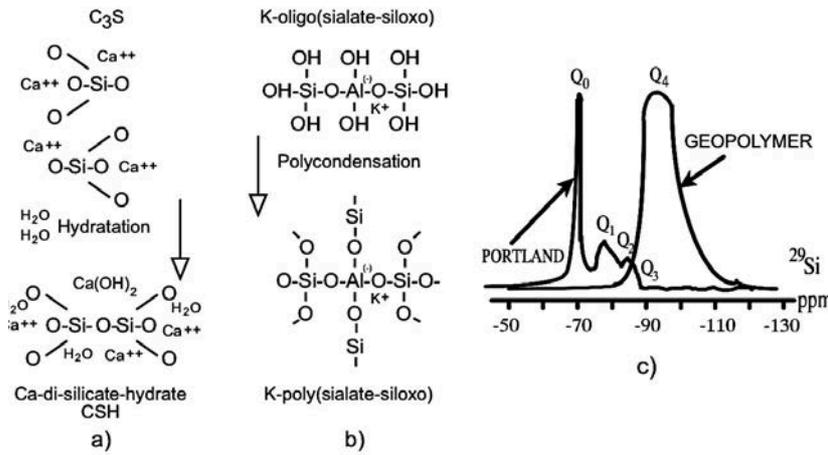


Figure 10: Portland cement chemistry vs Geopolymer cement chemistry: a) Hardening of Portland cement through simple hydration of Calcium Silicate into Calcium Di-Silicate hydrate (CSH) and lime Ca(OH)₂; b) Hardening (setting) of Geopolymer cement through polycondensation of Potassium Oligo-(sialate-siloxo) into Potassium poly(sialate-siloxo) cross linked network; c) ²⁹Si NMR spectra.

Fig. 10 compares the two systems: on the left, the hardening of Portland cement through simple hydration; in the center the hardening (setting) of Geopolymer cement through polycondensation; on the right, the corresponding ²⁹Si NMR spectra. ²⁹Si NMR spectra clearly show the difference in molecular structure. For Portland, in the hydrated CSH, the silicon unit is of the type Si(Q₀) for calcium silicate monomers, with

also some amount of calcium silicate oligomer of types Si(Q₁) and Si(Q₂).

Alkali-activated-materials scientists
substitution of Ca with Na, K

Portland cement
CaO.SiO₂.H₂O Calcium Silicate Hydrate
C-S-H

Geopolymer
Na₂O.2SiO₂.Al₂O₃.H₂O Sodium-Silico-aluminate-Hydrate
N-A-S-H

K₂O.2SiO₂.Al₂O₃.H₂O Potassium-Silico-aluminate-Hydrate
K-A-S-H

By contrast, for geopolymer, the structure is polymerized into a silico-aluminate, three-dimensional network of the type K—poly(sialate-siloxo) wherein the silicon unit is of the type Si(Q₄).

Figure 11: Portland cement chemistry yields CSH small hydrate molecule, and states Geopolymer chemistry is based on NASH and KASH.

Portland cement chemistry starts with calcium silicate hydration and end up with the so-called calcium silicate hydrate CSH. Alkali-activated cement materials scientists just substitute calcium with sodium and potassium for geopolymer. They claim that one gets sodium-alumino-silicate hydrate

NASH and potassium-alumino-silicate hydrate KASH (Fig. 11).



By doing so, they assert to understand geopolymer chemistry, which is wrong. By arguing that the end result is a simple molecule, a hydrate, or a precipitate, they ignore the scientific facts described in Fig. 10, namely the production of a polymeric network.

Figure 12: 2016 International Conference on Durability of Concrete Structures.

Other scientists are now recognizing this error. For example, one team presented a paper at a recent conference (Fig. 12).

The title reads (Fig. 13): *Study on the Disposition of Water in Fly Ash-Based Geopolymers Using ATR-IR*. The title is a little misleading and seems to be focusing on another issue. But the abstract written by the Australian-Chinese team provides clear information which supports our present statement: “This paper addresses the question of whether the main product of low calcium fly ash-based geopolymer is a hybrid namely sodium alumina silicate hydrate NASH. The answer to this question is important for understanding geopolymer characteristics.”

Study on the Disposition of Water in Fly Ash-Based Geopolymers Using ATR-IR

Jian Liu and Yuan Fang
School of Civil Engineering, Shenzhen University, China

Obada Kayali
School of Engineering and Information Technology, University of New South Wales, Canberra, Australia

ABSTRACT

This paper addresses the question of whether the main product of low calcium fly ash-based geopolymer is a hydrate, namely, sodium aluminosilicate hydrate (N-A-S-H). The answer to this question is important for understanding geopolymer characteristics.....

Figure 13: Paper title and Abstract of the paper presented by J. Liu, Y. Fang and O. Kayali.

Their study demonstrates that Infrared spectroscopy does not show the presence of water (or hydrate). They write: "... The assumption that the main product of geopolymer is NASH is not favored ..." This is a jargon that is spoken in a politically correct language, yet, it clearly means that the alkali-activated definition with its NASH / KASH is false.

Geopolymers
high molecular, macromolecules, polymers

Alkali-activated Materials are not POLYMERS.

They cannot be called GEO-POLYMERS

2 very different systems!

It is a big scientific mistake to use both as synonyms.

Alkali-activation is a wrong terminology for geopolymers.

Fig. 14 summarizes our claim, namely that geopolymers are high molecular structures or macromolecules, in other words : polymers. On the opposite, Alkali-activated materials AAM are based on a low-molecular chemistry with small molecules and are not polymers. It is therefore obvious that they cannot be called Geo-Polymers. Geopolymers and AAM are 2 very different chemical systems.

Figure 14: Why AAM are not Geopolymer?

It is a big scientific mistake to use both as synonyms. Alkali-activation is a wrong terminology for geopolymers.

of geopolymerization. From a pure chemical reaction

point of view we prefer using the most precise term of "alkalination". For the geopolymer preparation process, nothing is left to chance. There are 6 precise steps displayed in Fig. 15.

Alkali-activation
first step of geopolymerization?

1. alkali-activation (*alkalination*)
2. Depolymerization of silicates
3. Gel formation of oligo-sialates
4. Polycondensation
5. Reticulation, networking
6. Geopolymer solidification

Figure 15: The 6 steps of geopolymerization.

The preparation process follows the chemical reaction and each step is connected with a process, namely:
- 1) Mixing (K-Na) silicate and metakaolin/or slag/or fly ash.
- 2) Mixing time and mixing method.
- 3) Resting time.
- 4) Starting to harden.
- 5) and 6) Hardening.

"Are there some other activators instead of NaOH ?"

First: there is no geopolymer "*activator*".
There is a "*reagent*" (reactive ingredient) or "*hardener*";
alkalis (NaOH, KOH, LiOH), Na-silicates, K-silicates

Second: there is *NOTHING to activate*.
Metakaolin MK-750 is by nature *super-reactive*;
glass in fly ash is *easy to depolymerize*, etc.

Those who continue to mix up alkali-activation with geopolymerization, wonder whether there are other activators than their basic NaOH. The answer is displayed in Fig. 16 and is self-explicit.

Figure 16: There is no activator, only hardener or reagent.

There is no "activator" because we are dealing with chemically reactive ingredients.

Geopolymerization does not require the entire dissolution of inert or crystalline alumino-silicates.

To sum up: AAM are not polymers, so they cannot be called "geopolymers".

Part 4 (2017): NASH / KASH is an invalid terminology

In 2016, a paper published by a group of scientists determined that there is no presence of NASH or KASH in geopolymer cement (see part 3 above).



**INSTITUT
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Prof. Joseph DAVIDOVITS

Why Alkali Activated Materials
are **NOT** Geopolymers ?

Part 4: NASH / KASH is an Invalid Terminology

Excerpt from the keynote:
State of the Geopolymer R&D 2017

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According to AAM specialists from RILEM
“GEPOLYMER” is a type of
alkali-alumina-HYDRATE, a precipitate,
N-A-S-H, K-A-S-H
Nothing else !!!

WRONG

In this short excerpt, I explain this result by the true polymer nature of geopolymer chemistry. **You will learn what true NASH and KASH are, and in which context they are actually used.** AAM and geopolymer cement (wrongly shorten by some as “geopolymers”) are two very different and separate chemistry (a hydrate/precipitate that is a monomer or a dimer versus a true polymer). None is a subset of the other or its derivative which leads to confused interpretations.

Got to: <https://www.geopolymer.org/faq/alkali-activated-materials-geopolymers/> and on YouTube.

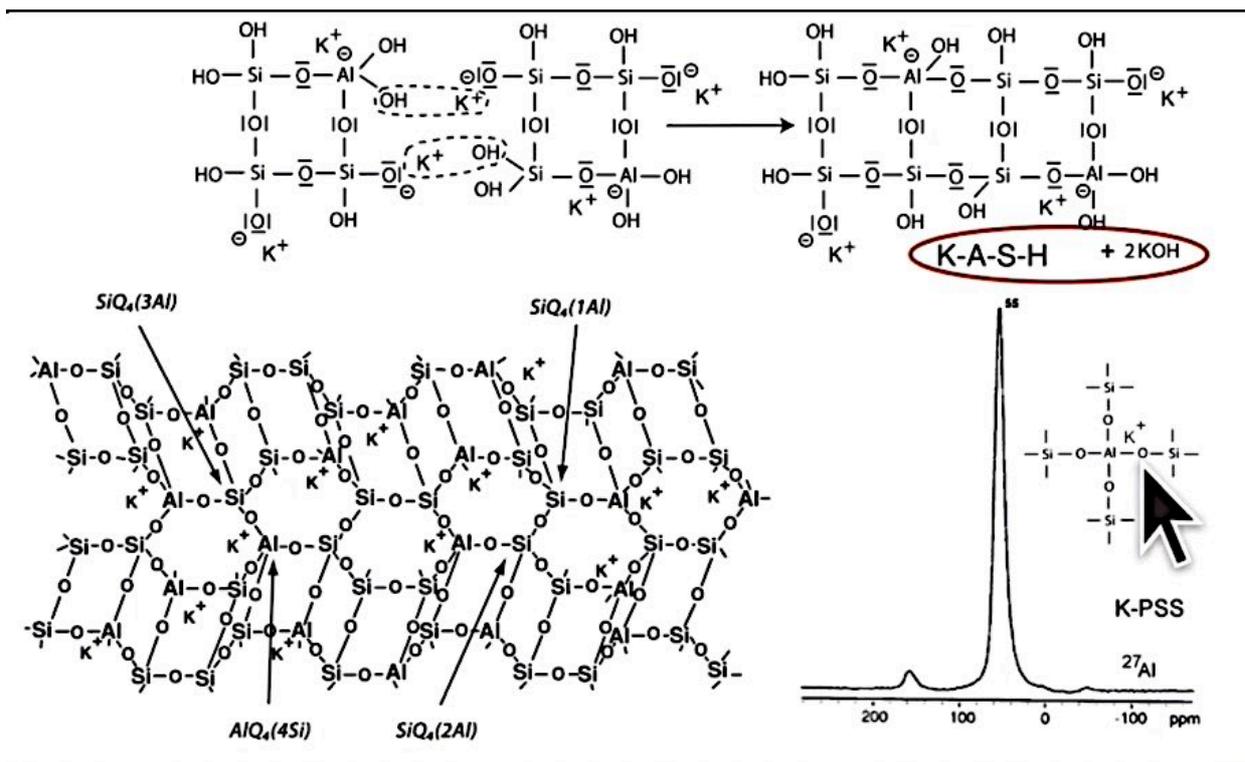


Figure 17: Geopolymerization with intermediary oligo-sialate-hydrate formation, top part right, wrongly called NASH/KASH by cement scientists. This hydrated molecule polycondenses into a fully reacted 3D geopolymer network. Right, 27Al-MAS-NMR spectrum for K-poly(sialate-siloxo) K-PSS geopolymer.

Alkali-activated cement materials scientists just substitute calcium with sodium and potassium for geopolymer. They claim that one gets sodium-alumino-silicate hydrate NASH and potassium-alumino-silicate hydrate KASH. The hydrate terminology for calcium-based is correct, because the cation Ca⁺⁺ is practically insoluble in water. Therefore, the hydrate is chemically stable and does not generate leachates. This is not the case for the cations Na⁺ and K⁺ which are very soluble in water. A hydrate such as NASH or KASH will very easily leach out its cations Na⁺ and K⁺.

I have a beautiful example below which illustrates this behavior.

(12) **United States Patent**
Skorina et al.

(10) Patent No.: **US 9,340,465 B2**
(45) Date of Patent: **May 17, 2016**

(54) **ALKALI METAL ION SOURCE WITH MODERATE RATE OF ION RELEASE AND METHODS OF FORMING**

(56) **References Cited**
U.S. PATENT DOCUMENTS

There is a growing need for alternative sources of alkali metals, such as, but not limited to, potassium ... (traditional potassium fertilizing agent) making local manufacturing of potassium fertilizer increasingly attractive....

Therefore, a need exists to produce a source of potassium ion that **releases the nutrient (K cation) at a moderate rate**, lower than the infinite dissolution rate of a traditional salts, but faster than the rate generally exhibited by naturally-occurring minerals.

It is a US Patent issued in 2016 (Fig. 18), titled: “**Alkali Metal Ion Source with Moderate Rate of Ion Release and Methods of Forming**”.

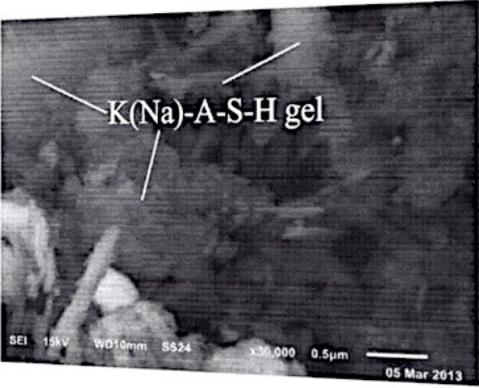
Figure 18: US Patent US 9,340,465, B2, issued May 17, 2016.

It describes a new approach in manufacturing potassium fertilizer, starting with geological raw materials (K-feldspar and the like).

U.S. Patent May 17, 2016 Sheet 6 of 9 US 9,340,465 B2

Claim: ...The method wherein the weight percent of K(Na)-A-S-H gel of the alkali metal ion source is between about 10% and about 100%.

Applicant: Massachusetts Institute of Technology M.I.T., Cambridge, Boston.



The main claim of the patent (see in Figure 19) is the production of KASH gel, potassium-alumino-silicate-hydrate, to make a fertilizer. The cation K+ should be leached out by water, when put in the earth and help fertilize soils in a wide range of countries.

Figure 19: MIT patent claiming the manufacture of KASH/NASH for K-fertilizer.

The terminology KASH is widely used here by the applicant who is the MIT, Massachusetts Institute of Technology, Cambridge, Boston.

This is logical here. MIT is not claiming that KASH is AAM, nor geopolymer.

N-A-S-H
Sodium Aluminosilicate Hydrate
Alkali-Activated Materials



But those material scientists who make AAM and NASH are producing a material which contains soluble alkali Na+ that will leach out, like in Figure 20.

Figure 20: AAM block with NASH efflorescence (white blooming).

Toowoomba-Brisbane-West Wellcamp Airport, by WAGNERS, Australia
October 2015



100,000 tonnes
Slag/fly ash-based geopolymer concrete EFC (Earth Friendly Concrete)

On the opposite, those material scientists and civil engineers who follow geopolymerization precise process and chemistry are manufacturing advanced geopolymer concrete, like in Figure 21.

Figure 21: Geopolymer concrete (2015).

Afterword:

24 years ago, I made a presentation at the First International Conference on Alkaline Cements and Concretes, titled: *Properties of Geopolymer Cements*, in Kiev, Ukraine (1994). It was there, at Kiev, that V. D. Glukhovski developed in the 1960-1970s the concept of alkali-activated materials which he had coined "Soil-cements". The excerpt below was already discussing the issue, "AAM are not Geopolymers".

The full text is available here in *Research Gate* and also at the Geopolymer Institute Library, at <https://www.geopolymer.org/category/library/technical-papers/>, paper #8: *Alkaline Cements and Concretes, Properties of Geopolymer cements*.

(.....)

TERMINOLOGY: GEOPOLYMER VS. ALKALI-ACTIVATED ALUMINO-SILICATE

We mentioned above that, because alkalis are generally thought of as the cause of alkali-aggregate-reaction, the present tendency is to avoid any addition of alkali in ordinary Portland cement. According to the terminology generally in use by cement scientists and concrete experts, both cementitious systems discussed above in terms of the relationship between alkali-aggregate-reaction and ^{27}Al MASNMR spectroscopy, should be named «alkali-activated cements» [47]. Yet, the cement which resonates at 55 ppm, $\text{AlQ}_4(4\text{Si})$ building units (Fig.17 and Table 8), does not generate any deleterious alkali-aggregate-reaction (Fig. 15, ASTM C227 bar expansion test), whereas the cement which resonates at 66 ppm, $\text{AlQ}_3(3\text{Si})$ building units, reacts with susceptible silica. In addition, in the first cement category, the SiO_4 tetrahedrons are of the three-dimensional cross-linked framework (Q_4) type, $\text{SiQ}_4(3\text{Al})$ - $\text{SiQ}_4(2\text{Al})$ - $\text{SiQ}_4(1\text{Al})$ (Fig. 16), and are essentially different from the $\text{Si}(\text{Q}_0)$, $\text{Si}(\text{Q}_1)$, monosilicate and disilicate structures of calcium silicate hydrates, which are the main constituents of the second alkali-activated Portland cement category. It becomes obvious that the terminology in use generates confusion and is a severe obstacle for any further beneficial scientific and commercial developments of alkali cementitious systems.

The concept of Geopolymer and Geopolymerization is well accepted in the science and technologies involving advanced materials. Geopolymers result from the polycondensation of polymeric aluminosilicates and alkali-silicates, yielding three-dimensional polymeric frameworks. Cement scientists should admit that cements involving alkali contents of 9.2% and higher, which do not generate any dangerous alkali-aggregate reaction, cannot comply with the existing codes and guidelines and should get a distinctive appellation. To call them Geopolymer cements or Geopolymeric cementitious compounds or Poly(sialate) cements, focuses on their unique properties without being confused with regular alkali-activated Portland cements. (.....) *End of excerpt.*