Application of geopolymers as adsorbents in wastewater treatment – project GeoSorbents

Tero Luukkonen[1,2], Emma-Tuulia Tolonen[1,2], Hanna Runtti[2], Kimmo Kemppainen[1], Ulla Lassi[2,3]

[1]Kajaani University of Applied Sciences, Kuntokatu 5, FI-87101, Kajaani, Finland
[2]University of Oulu, Research Unit of Sustainable Chemistry, FI-90014, University of Oulu, Finland
[3]University of Jyvaskyla, Kokkola University Consortium Chydenius, Unit of Applied Chemistry, Talonpojankatu 2B, FI-67100, Kokkola, Finland

GEOPOLYMERS

Geopolymers are three-dimensional cross-linked inorganic alumino-silicate materials with an amorphous structure (Fig. 1).

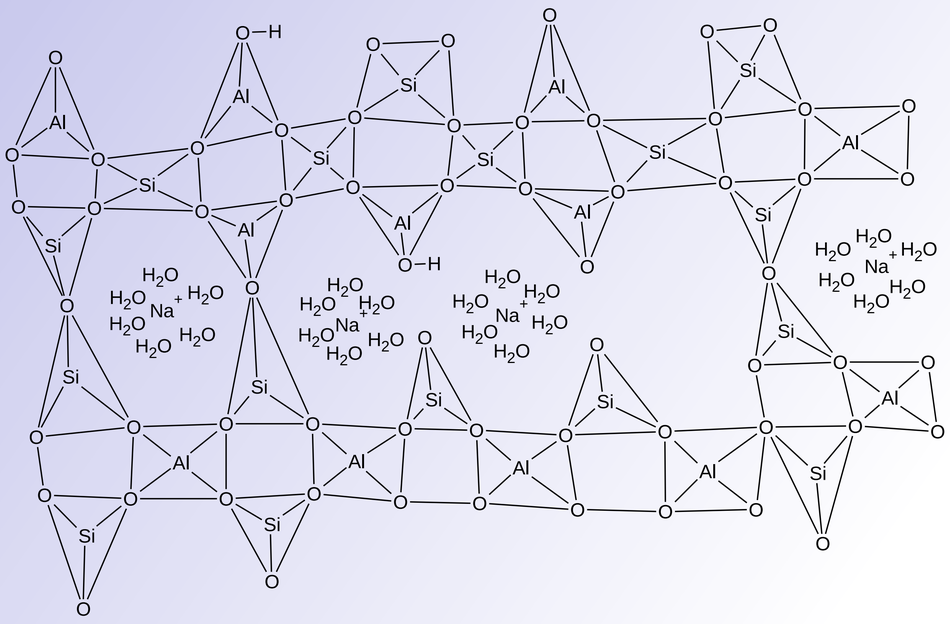

Fig. 1. A semi-schematic presentation of the geopolymer structure according to Barbosa (2000).

USE OF GEOPOLYMERS IN WASTEWATER TREATMENT

Geopolymers have a permanent negative charge in their framework structure arising from the valency differences between Al and Si atoms. The negative charge is balanced by exchangeable cations, such as Na^+. Consequently, the basis of the utilizing geopolymers in wastewater treatment is **cation exchange**. Results obtained with various geopolymer adsorbents as reported in the literature are shown in Table 1.

- Adsorption capacity, porosity, and specific surface area of raw materials increase substantially as a result of geopolymerization.
- Zeta potential of geopolymers is negative.
- Geopolymer adsorbents can be regenerated with e.g. NaCl / NaOH solutions.

PREPARATION OF GEOPOLYMER ADSORBENTS

Geopolymers are prepared by reacting aluminosilicate raw materials (such as fly ash, slags from metal industry, calcined clays or other natural minerals) with alkali metal hydroxide and/or silicate or phosphoric acid solution. The synthesis in alkaline media is more widely studied and considered industrially more important. The commonly used synthesis methods are shown in Fig. 2. Additionally, geopolymer adsorbents can be prepared with the granulation-geopolymerization process (Fig. 3).

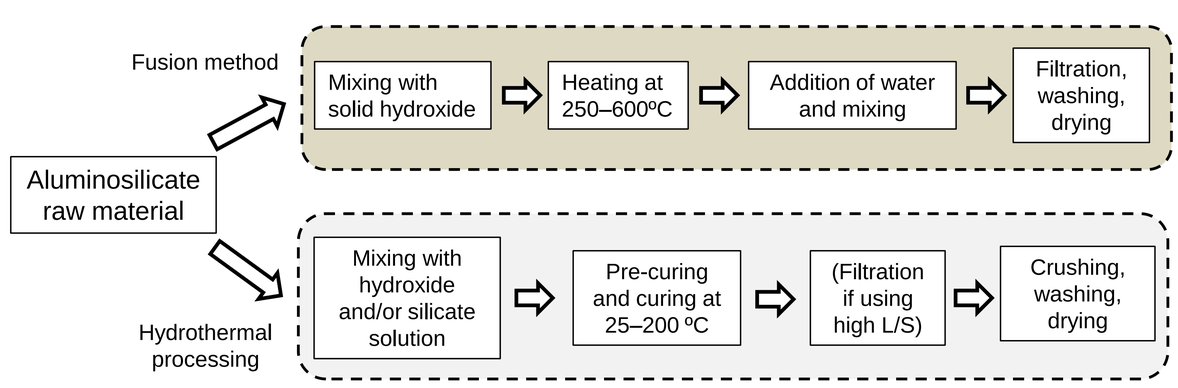

Fig. 2. The synthesis methods of geopolymers as reported in the literature.

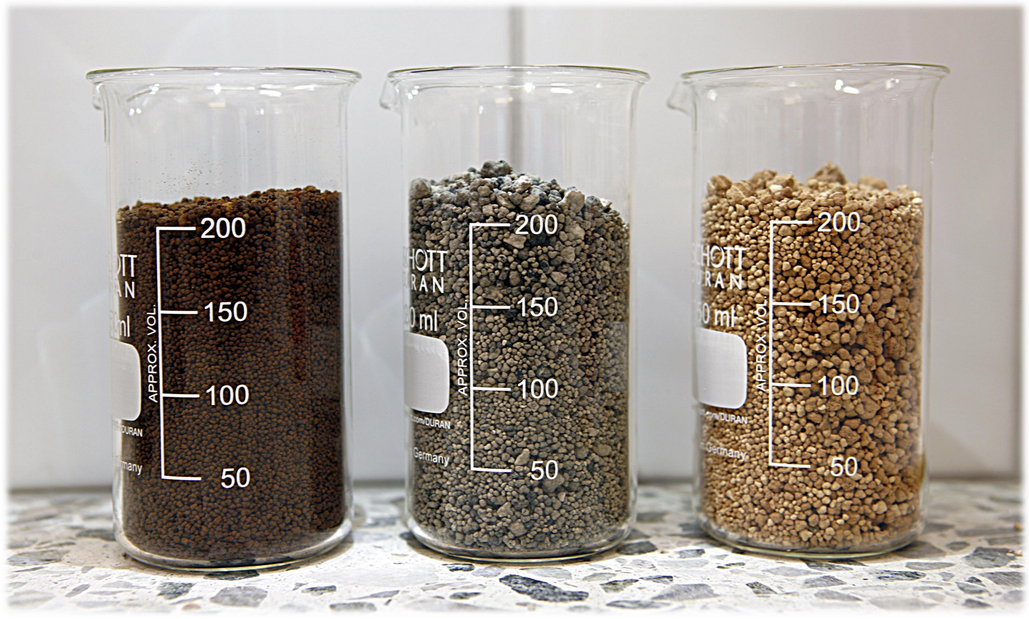

Fig. 3. Geopolymer granules produced with the granulation-geopolymerization process.

Table 1. Results reported in the literature with geopolymer-based adsorbents.

Raw material	Adsorbate	C [mg/L]	Optimum pH	Adsorption capacity [mg/g]	Reference
Metakaolin [a]	Methylene blue	10–50	3	4.26	Khan et al. 2015
Coal fly ash	Methylene blue	32	n.d.	18.3	Li et al. 2006
Coal fly ash	Crystal violet	41	n.d.	17.2	Li et al. 2006
Metakaolin	NH_4^+	10–1000	4–8	21.1	Luukkonen et al. 2015
Blast furnace slag	Ni(II), As(III), Sb(III)	2	6	4.42 (Ni), 0.52 (As), 0.34 (Sb)	Luukkonen et al. 2015
Metakaolin	Cs^+	50–500	n.d.	57.8	López et al. 2014b
Metakaolin	Cs^+	50–500	n.d.	50.8	López et al. 2014a
Metakaolin, fly ash	Cs^+	266	7	565	Chen et al. 2013
Coal fly ash	Cd^{2+}	10–100	5	26.5	Javadian et al. 2013
Metakaolin, fly ash	Sr^{2+}	175	7–11	85.1	Chen et al. 2013
Metakaolin, fly ash	Co^{2+}	118	5–11	153	Chen et al. 2013
Metakaolin	Pb^{2+}	50–500	n.d.	63.4	López et al. 2014b
Metakaolin	Pb^{2+}	50–300	4–5	147	Cheng et al. 2012
Fly ash	Pb^{2+}	100	5–6	167	Al-Zboon et al. 2011
Fly ash	Cu^{2+}	50–250	n.d.	92	Wang et al. 2007
Fly ash (A type)	Cu^{2+}	350–748	n.d.	77.3	Mužek et al. 2014
Metakaolin	Cu^{2+}	50–500	n.d.	59.2	López et al. 2014b
Metakaolin	Cu^{2+}	10–120	5	52.6	Ge et al. 2015
Kaolinite, zeolitic tuff	Cu^{2+}	10–100	6	52.7	Yousef et al. 2009
Metakaolin, zeolitic tuff	Cu^{2+}	250	n.d.	7.80	Alshaaer et al. 2014
Metakaolin	Cu^{2+}	50–300	5	48.8	Cheng et al. 2012
Metakaolin	Cr^{3+}	50–300	4	19.9	Cheng et al. 2012

References

Alshaaer M, Zaharaki D & Komnitsas K (2014), Desalin. Water Treat.

Al-Zboon K, Al-Harahsheh MS & Hani FB (2011), J. Hazard. Mater. 188(1–3): 414–421.

Barbosa VFF, MacKenzie KJD, Thaumaturgo C (2000), Int. J. Inorg. Mater. 2: 309–317.

Chen Y, Tong Y, Pan R & Tang J (2013), Adv. Mater. Res. 704: 313–318.

Cheng TW, Lee ML, Ko MS, Ueng TH & Yang SF (2012), Appl. Clay Sci. 56: 90–96.

Ge Y, Cui X, Kong Y, Li Z, He Y & Zhou Q (2015), J. Hazard. Mater. 283: 244–251.

Javadian H, Ghorbani F, Tayebi H & Asl SH, Arab. J. Chem., in press

Khan MI, Min TK, Azizli K, Sufian S, Ullah H & Man Z (2015), RSC Adv. 5(75): 61410–61420.

Li L, Wang S & Zhu Z (2006), J. Coll. Interf. Sci. 300(1): 52–59.

López FJ, Sugita S & Kobayashi T (2014a), Chem. Lett. 43(1): 128–130.

López FJ, Sugita S, Tagaya M & Kobayashi T (2014b), J. Mater. Sci. Chem. Eng. 2: 16–27.

Luukkonen, T., Sarkkinen, M., Kemppainen, K. (2015), Appl. Clay Sci., in press.

Luukkonen, T., Runtti, H., Niskanen, M., Tolonen, E.T., Sarkkinen, M., Kemppainen, K., Rämö, J., Lassi, U., J. Environ. Manage., accepted manuscript.

Mužek MN, Svilovic S & Zelic J (2014), Desalin. Water Treat. 52(13–15): 2519–2526.

Wang S, Li L & Zhu ZH (2007), J. Hazard. Mater. 139(2): 254–259.

Yousef RI, El-Eswed B, Alshaaer M, Khalili F & Khoury H (2009), J. Hazard. Mater. 165(1–3): 379–387.