$CaCO_3$ precipitation in drainage systems of subsurface infrastructure – Monitoring approaches and crystal growth control

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Methodological approaches and enhanced process understanding interconnecting fundamental research with (geo)technical settings and problems benefit from each other regarding the calcium carbonate chemical system (cf. Boch 2020). The effective draining of subsurface infrastructure is frequently faced with unwanted mineral precipitation (Fig. 1A) based on elevated mineral and gas contents of the discharging groundwater being of high relevance for cleaning downtimes and maintenance of the infrastructure (Eichinger et al. 2020). Owing to regional geology in Austria (limestones, calcareous contents) and construction materials used in subsurface infrastructure (concrete, mortar), carbonate deposits consisting of various $CaCO_3$ polymorphs and accessory constituents are most abundant in the drainage systems (Fig. 1B) next to iron precipitates and interacting biomass (bacterial biofilms).

In the context of existing subsurface infrastructure (e.g. Semmering highway tunnels) and new excavations (e.g. Koralmtunnel) the recent years strongly increased the understanding of critical processes based on in-situ monitoring campaigns as well as related laboratory analyses and computer modelling. The drainage system and maintenance strategies were adapted based on the implementation of an underground "sinter test track" (Fig. 1C) and local test fields with typical construction materials but different constructive designs (Wedenig et al. 2022). The on-site and online application of sensors/data loggers and mobile instrumentation in combination with sample analyses provided new insights to water-gas-mineral-biology-substrate interaction and to the major controls of calcium carbonate precipitation.

An approach to systematically influence the nucleation and crystal growth of the unwanted deposits consists in the application of specific chemical additives ("green inhibitors") to the ground-/drainage waters. In laboratory and field tests various substances (e.g. polyaspartic acid) and concentrations were investigated and a new test procedure was developed (Wedenig et al. 2021). This resulted in new insights concerning relevant parameters such as $CaCO_3$ supersaturation, pCO_2, Mg/Ca and water flow conditions in relation to mineralogy (polymorphism; Fig. 1D), crystal shapes/sizes, substrate effects (e.g. different plastic types) and further regarding proactive controls on fabrics and material consistency (hardness) of the deposits.

Figure 1. Diverse mineral precipitates (A) in the course of continuous groundwater discharge underground can block a tunnel drainage system (B) and were investigated by in-situ field tests (C) targeting an increased process understanding of the precipitation conditions (e.g. D: $CaCO_3$ polymorphism) as well as efficient countermeasures (e.g. optimized drainage design, addition of inhibitors).

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