Statens vegvesen
Norwegian Public Roads Administration

Purification practices of water runoff from construction of Norwegian tunnels

Status and research gaps

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- Norway has 1043 road tunnels
  - 34 of these are subsea
- Every year 20-30 km new tunnel are built

Tunneling - Effect on water quality

- In Norway, EU's Water Framework Directive was implemented and entered into force in 2007

- The directive aims to
  - coordinate all relevant authorities
  - achieve good ecological and chemical quality of waters and waterways within 2021

All Norwegian road construction projects must document the quality of water from site and the recipient's tolerance limit

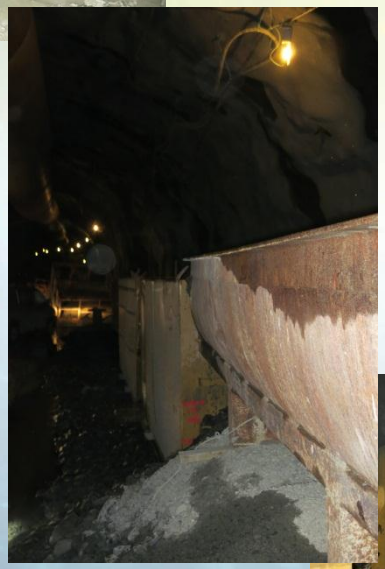
Water sources during tunnelling

- Drilling water
  - Consumption of rig with 3 booms: Typically 300 L/min
- Natural leakage from solid rock
  - Controlled by grout injection
  - Threshold value:
    - Often 10-25 L/min per 100m tunnel
    - 4 L/min also applied
- Incidental water inflow
  - 200 L/min a frequently used value

Contaminants in tunneling water

- Suspended particulate matter from rock and soil
- Natural rock as source of
  - acidic runoff
  - heavy metals
  - radioactivity (U → Ra, Rd)
- pH periodically up to 10-12
- N, NH_4^+ and NH_3 from shards with undetonated explosives
- Grouting chemicals
- Oil and chemical spills

Why and how is Norwegian tunneling water treated?



Suspended Solids

Detrimental effects:

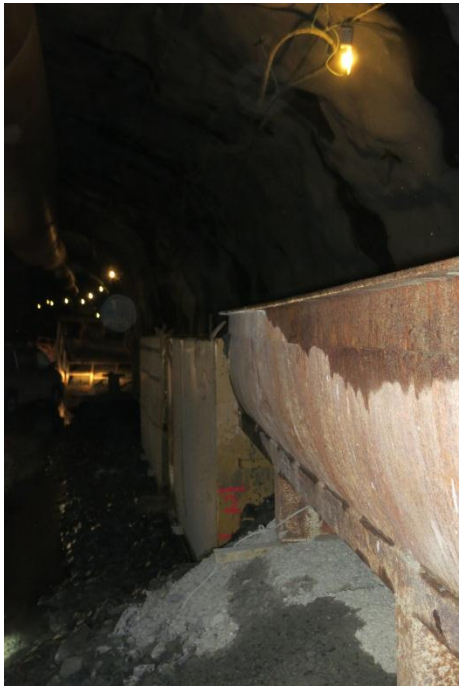
- Damages of fish gill tissue
- Reduced penetration of light
- Temperature changes
- Infilling of reservoirs and channels
- Altered spawning conditions
- Covering sources of fish food

- Suspended solids (SS) concentration by the working face: 5.000 – 10.000 mg/L
- Well dimensioned sedimentation pools can purify tunneling water to approximately 400 mg/L SS

Suspended Solids

- Suspended solids concentration < 100 mg/L can be obtained by
  - addition of coagulation chemicals, often in combination with acid (HCl)
  - filters

Oil separators



- Removal of oil that has not been retained by ditches and thresholds
- Normally positioned after the sedimentation basins

pH adjustment

- Tunneling water pH can periodically be up to 11-12
- pH is adjusted with respect to
  - aquatic life in the recipient
  - improved particle sedimentation
- pH is adjusted by addition of acid (HCl)
  - demands thorough follow-up of the system
- pH can be adjusted by addition of carbon dioxide

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

  - Will not lower the pH of water below 7.0: More environmental friendly than acid
  - Norwegian construction sites have not yet gained experience with this method

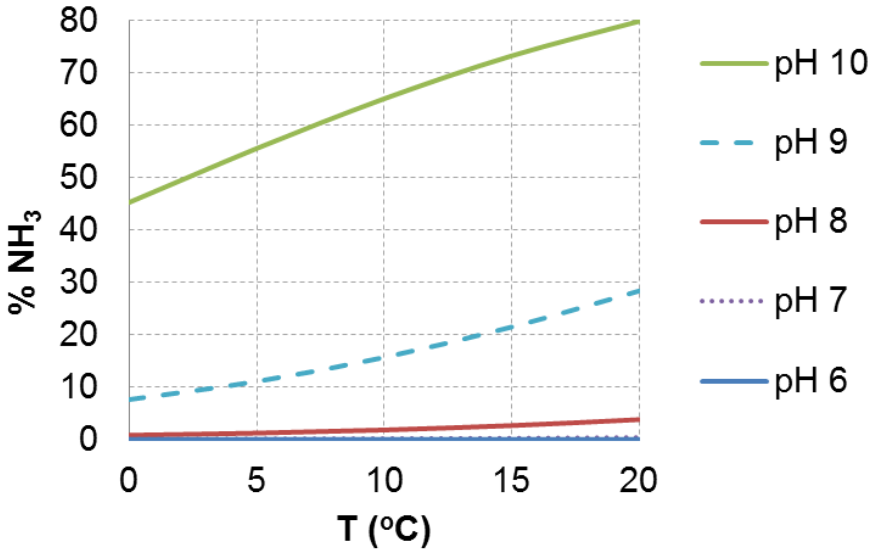
Nitrogen – ammonia – ammonium

- NH_4NO_3 is a common blasting agent

- NH_4NO_3 is readily water soluble
  - Eutrophication of marine waters
  - Formation of toxic NH_3 at elevated pH

- Common treatment practices:
  - Adjusting the pH of the tunneling water
  - Hosing down blasting rock before deposition

$$NH_3 + H_3O^+ \leftrightarrow NH_4^+ + H_2O$$



The NPRA has not gained practical experience with nitrogen-removal technologies (absorbents, ion exchange, denitrification…..)

Recirculation of drill rig water

- Conditions
  - Particles in the water must be removed to avoid damage to the machinery
  - pH must be adjusted with respect to the working environment
- Effects
  - \+ Reduced water quantities transported out of the tunnel
    → Reduced dimensions of the water purification systems
  - \+ Recirculation motivates the contractor to operate the installations (i.e. pH regulation or addition of coagulants) optimally

Conclusions

- Technology and degree of water treatment varies from project to project depending on
  - vulnerability of recipient
  - know-how of local authorities and technologists on the project
- In order to ensure quality of tunneling water, research and development is needed in terms of
  - identifying pollutants and concentrations
  - identifying biological effects and limits of tolerance
  - proper handling of naturally acidic and radioactive rock masses
  - improved water purification systems in terms of particle sedimentation, removal of nitrogen/ammonia and pH regulation