Hydrochemistry & microbiology of groundwater in the Kabul Basin (Afghanistan)

Dr. Georg Houben

Joint Afghan-BGR-Project

on behalf of the

Federal Foreign Office of Germany
Waste and sewage disposal close to water wells

Sewage pipe!

Foto: Tünnermeier
Uncontrolled waste disposal
290 well sites, 188 water samples analysed (65%)

- parameters measured in-situ: pH, Eh, EC, O₂, T, nitrate (test kit), HCO₃⁻ (titration)
- GPS-coordinates, site description, some geological logs, depth, diameter, pump types
Locations of sampled wells (2004)

188 wells sampled:

- full chemical analyses
- trace elements
- microbiology

Good coverage of urban area
Specific electrical conductivity in Kabul

- electrical conductivity (EC) is a measure of the dissolved salt content
- most waters in Kabul show elevated to high mineralisation → evaporation
- some waters are unsuitable for human consumption (EC > 1,500 µS/cm)
Specific electrical conductivity in Kabul

Satellite image of the Kabul basin

former swamp areas dried up due to abstraction and lack in precipitation

both groundwater and soil salinisation
Groundwater pH in the Kabul Basin

near neutral ☺, very narrow distribution
Hardness of groundwater

Hardness of water = dissolved carbonate content
Hard waters safe to drink **BUT**
can cause plugging of wells, pipelines, household appliances... 😞
Hydrogeology of the Kabul Basin

Hardness of groundwater in Kabul

> 80 % of all samples are hard to very hard
Redox conditions in Kabul

- slightly oxic
- little iron, little manganese 😊
- no ammonia, little nitrite 😊
Nitrate in Kabul

Almost half of all samples above WHO limit of 50 mg/l dangerous for babies and smaller children ("blue baby disease")

Source: sewage water
Spatial distribution of nitrate in Kabul

Highest nitrate concentrations mostly in densely populated areas

Hydrogeology of the Kabul Basin
Borate in Kabul

almost all samples above WHO limit

potential sources:
- borate used as bleaching agent in washing powders
- natural enrichment in evaporative environments (borate highly soluble)
Trace metals and metalloids

low concentrations due to neutral pH and oxic redox potential 😊
Incrustation potential

<table>
<thead>
<tr>
<th>Incrustation type</th>
<th>Mineral phases</th>
<th>Dissolved concentrations</th>
<th>SI*</th>
<th>Incrustation potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate</td>
<td>Calcite</td>
<td>high</td>
<td>&gt; 0</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td>Dolomite</td>
<td>high</td>
<td>&gt; 0</td>
<td>high</td>
</tr>
<tr>
<td>Alkaline earth sulphates</td>
<td>Gypsum</td>
<td>high</td>
<td>&lt; 0</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>Anhydrite</td>
<td>high</td>
<td>&lt; 0</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>Baryte</td>
<td>very low</td>
<td>&gt; 0</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>Metal sulphides</td>
<td>very low</td>
<td>&gt; 0</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>Pyrite</td>
<td>very low</td>
<td>&gt; 0</td>
<td>low</td>
</tr>
<tr>
<td>Ochre incrustation</td>
<td>&quot;Iron oxides&quot;</td>
<td>very low</td>
<td>&lt; 0</td>
<td>very low</td>
</tr>
<tr>
<td></td>
<td>&quot;Manganese oxides&quot;</td>
<td>very low</td>
<td>&lt; 0</td>
<td>very low</td>
</tr>
<tr>
<td>Metal sulphides</td>
<td>&quot;FeS&quot;</td>
<td>very low</td>
<td>&lt; 0</td>
<td>very low</td>
</tr>
<tr>
<td></td>
<td>Pyrite</td>
<td>very low</td>
<td>&lt; 0</td>
<td>very low</td>
</tr>
<tr>
<td>Aluminium hydroxide</td>
<td>Gibbsite</td>
<td>very low</td>
<td>&lt; 0</td>
<td>very low</td>
</tr>
<tr>
<td>Silification</td>
<td>&quot;SiO$_2$&quot;</td>
<td>moderate to high</td>
<td>&gt; 0</td>
<td>moderate</td>
</tr>
</tbody>
</table>

* SI > 0: water oversaturated with respect to mineral phase, mineral can precipitate

SI < 0: water undersaturated with respect to mineral phase, mineral can be dissolved further

endangers operation of wells, pipelines, boilers…….
Microbiology and drinking water hygiene

Normal groundwater microorganisms are not dangerous to human health.

Problems arise from faecal bacteria from sewage water:

- water-borne bacterial disease: e.g. cholera
- water-borne viral disease: e.g. hepatitis A

Detection of individual pathogenic bacterial and viral species is extremely difficult.

→ INDICATOR ORGANISMS
  
  e.g. faecal or gastrointestinal bacteria (*Escherichia, E. coli*), not pathogenic

Large numbers of bacteria indicate the simultaneous presence of viruses.
About half of all distribution networks and wells with hand pumps are polluted by faecal bacteria. Three quarters of shaft wells suffer from the same problem.
Irregular spatial distribution of microbially polluted samples causes?
- heterogeneity of aquifer
- heterogeneity of input

Loess layers are of utmost importance for groundwater protection!

Red = bacteria present
Green = no bacteria present
Cess pits and their influence on shallow groundwater

sewage water causes:

- high nitrate input
- oxygen consumption
- hidden acid input
- high bacterial counts
Fluxes in the Kabul basin

enrichment of salts and nutrients through wastewater input and evaporation
How to overcome water pollution?

- collection of garbage → safe disposal or incineration
- sewage removal from cess pits in regular intervals → safe disposal
- construction of sewer system(s) and wastewater treatment plant(s) ($$$)
- conversion of regular cesspits to mini-treatment plants
- wait for some wet years to flush out pollutants by groundwater flow (?)
- awareness rising in the population (schools, university)
Summary

- neutral pH → high buffering capacity, low trace element mobilisation
  **BUT** high hardness

- slightly oxic redox potentials, low iron, manganese & trace metal conc.

- water quality deteriorates due to massive uncontrolled wastewater input
  (nitrate, borate, micro-organisms...)

- high evaporation rates amplify salt accumulation

- growing population poses threat to both quantity and quality of water

- wastewater treatment & garbage disposal schemes must be implemented to overcome problems
Further information may be downloaded from:

http://www.bgr.de/b1hydro/fachbeitraege/c200501/kabul basin part I.pdf

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(you find the link in your conference material)
THANK YOU

FOR YOUR ATTENTION!!

Questions are welcome!