Development of composting plant rock surrounding pollution. Case study – Točna in Příbor, The Czech Republic

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Abstract. Composting plant Točna utilize and modifies biologically biodegradable waste by aerobic fermentation method. After emergency leakage of leachate water in 2010 the quality of rock surrounding is being regularly monitored in the range of indicators: pH, conductivity, COD (chemical oxygen demand, Cr), HCO₃⁻, Cl⁻, N-NH₄⁺, N-NO₃⁻, N-NO₂⁻ and humic substances. Technical adjustments of the interest area has been also made to prevent leakage of contaminated water. Locality monitoring system is ensured separately for shallow backfill aquifer and deeper quaternary aquifer. Protective hydraulic barrier is running at the same time to prevent effluent of shallow water to groundwater. Nitrogenous substances (above all ammonium ions) and humic substances belongs among main groundwater contaminants of the interest area. Peak concentration level of this substances is connected with shallow backfill aquifer, near south-east and east edge of the locality, not in general quaternary water direction. From long-term monitoring results follows that concentration of monitored substances is gradually decreasing, especially in water connected with backfill layer. Drier weather of last year helps to this development. Quality of quaternary aquifer is not influenced significantly, only locally in spots, in the places of both aquifers connection where increase of ammonium ions occurs as result of humic substance decomposition. In effect, monitored substances are not disseminated in quaternary aquifer.

1. Introduction
Composting plant Točna utilize and modifies biologically biodegradable waste by aerobic fermentation method. Fermentation area of composting plant is made of continuous paved asphalt concrete surface of c. 3 000 m². The area is declined to the gathering tanks where liquid products of fermentation (leakages) and rainfall water coming from area are collected.

Frequent leakages of dark brown water coming from shallow rock surrounding onto the surface used to occur in the past (before 2009). Brown water appeared in the trough which was designed to collect rainwater and is located along the entrance road leading to the composting plant. Brown water outflowed from the through to the road ditch and to natural surroundings.

Remedial measures included building of the monitoring system, introduction of the regular monitoring of groundwater quality in the range of pollution indicators: pH, conductivity, COD (chemical oxygen demand, Cr), HCO₃⁻, Cl⁻, N-NH₄⁺, N-NO₃⁻, N-NO₂⁻ and humic substances, the operation of hydraulic barrier and partial reconstructive works.

The monitoring system of the locality was built in 2009 (Zakova, 2009) and consists of PN boreholes (no. 1 to 7) for shallow backfill aquifer and from PK boreholes (no. 1 to 4) for deeper quaternary aquifer. Protective hydraulic barrier is being operated in PN-1 borehole. Due to the shallow
groundwater pumping, the absence of shallow water leakage into the ditch and spreading of the water onto the terrain surface is ensured. Reconstructive technical works of the area and of the tanks have been made during the year of 2010 to 2015 which ensured tightness of the surface of the composting area and of the leachate water retaining tanks. 

The interest area is located in the Czech Republic, in Moravian-Silesian region, at the southwestern edge of the town Příbor, in the area of the former agricultural company. The terrain surface is plane. Altitude varies from 296 to 299 m above the sea level. The nearest recipient of the surface water is a nameless left-side inflow of Lubina that flows c. 300 m eastwards the locality. The interest area layout with its monitoring system is stated in the following picture.

![Figure 1. Locality of composting plant with monitoring wells.](image)

2. Geological and hydrogeological locality conditions

The following geological and hydrogeological facts have been verified by investigation works implemented to design remedial measures (Ondrasíková, 2008, 2010; Zakova, 2009).

- The area under the composting plant was excavated (brick clay mining) and filled by the material of unspecified type as well as the near old landfill ‘Na Točně’. Original locality geological sequence is: humous loam of 0.4m thickness in the top, clayey sandy loam layer of c. 3.0 m thickness, clayey sandy gravel layer of c. 3.0 to 3.5m thickness and finally surface of the basement rock at about 7m under the terrain (claystone of frýdecká layer of the late Cretaceous).

- Heterogeneous backfill layer of stony character with admixture of the slag, bricks, concrete and gravel has been verified in the area of the composting plant locality. The backfill layer is locally covered by discontinuous clayey backfill layer which is very often water-bearing by highly polluted water corresponding to the seepage water of the composted material. Original rusty brown loess loam was verified below backfill layer. Original clayey loam was removed in the Eastern part of the composting plant (around PK-1 and PN-3 boreholes). Backfill is located just on the permeable sandy gravel layer of Saale glaciation. The clayey layer separates backfill and quaternary aquifer.

- Hydraulic conductivity of backfill material was determined in the range of $2.10^{-4}$ to $4.10^{-7}$ m.s$^{-1}$ that shows to rather high to weak permeability of the material. According to its granularity,
bottom loess loam layer corresponds to clay of $1.10^9$ m.s$^{-1}$ hydraulic conductivity of slightly permeable surroundings. On the basis of the express pumping tests results, PN-1 borehole yield was determined at the level of c. 0,05-0,1 l/s, that is c. 4.3 to 8.6 m$^3$ of contaminated water per day.

- General groundwater flow direction is from southwest to northeast, towards the Lubina river valley that creates local erosion base. Maximum groundwater level in shallow aquifer is connected with the borehole PN-3 and its surroundings (about 297.5 m above the sea level). Groundwater flow direction of the backfill layer goes rather from southwest to northwest. According to the geological profile of the interest area, both aquifers are connected. Overflow from backfill to quaternary aquifer occurs in the area of PK-1 and PN-3 boreholes. Due to the construction of the bypass road in 2011, PN-4 and PN-5 boreholes and partially earth cut along the original road were dewatered. Groundwater level is closely connected with the amount of precipitation in the interest area.

3. Methodology of work – field measurements, analytical method and evaluation

Groundwater sampling was carried out 3 times a year – in the spring, before the beginning of composting, during intensive operation in summer and after composting conclusion in autumn. During evaluation the data from 2010 to 2016 were implemented (Ondrasíkova 2010-2016). Long-term evaluation of rock surrounding quality is focused on humic substances and ammonium ions.

Sampling was implemented in accordance with the relevant standards and regulations. Groundwater samples were taken dynamically. Groundwater level was measured (an acoustic level meter G-20) before pumping in every well. Physio – chemical parameters of groundwater were observed during pumping. Measurement was made by field measuring device CyberScan in the range of pH, conductivity, temperature and total dissolved solids. Samples were taken to standard samplers after physio – chemical parameters stabilization or after drawing off of 3 volumes of borehole water. The analyses of groundwater and surface water samples were made by ALS Laboratory Group, ALS Czech Republic s.r.o. accredited by Czech Accreditation Institute. The methodology of indicators determination was:

- dissolved substances $105^\circ$C by gravimetry
- chlorides, bicarbonates by titration
- COD (chemical oxygen demand, Cr), Biochemical oxygen demand by titration
- Fe atomic absorption spectrometry
- N-NH$_4^+$, N-NO$_3^-$, N-NO$_2^-$ photometrically
- N-org by spectrophotometry
- humic substances by spectrophotometry

4. Results and Discussion

The primary contaminants of the investigated area were identified on the basis of seepage water quality that originates from the composting plant (Zakova, 2009). Values of chosen seepage water indicators are stated in following table. Seepage water has high content of humic substances, bicarbonates, ammonium ions, chlorides and potassium. Reaction of water is neutral to slightly alkaline.

Specific values of some substances occurring in seepage water from composting plant is the result of the used composting technology. Increased content of potassium mostly indicates existence of animal waste that can be added to improve final ratio of carbon / nitrogen in the compost. The value of pH should vary from 6 to 8 to ensure the activity of microorganisms. Adjustment of acid pH that is typical for organic matter mineralization is commonly implemented by burned lime addition.
Table 1. Selected indicators of leachate water.

| Indicator         | Concentration |
|-------------------|---------------|
| humic substances  | 11 100 mg/l   |
| HCO₃⁻             | 3 965 mg/l    |
| NH₄⁺              | 170 mg/l      |
| Cl⁻               | 1 277 mg/l    |
| SO₄²⁻             | 316 mg/l      |
| K                 | 3 140 mg/l    |
| Ca                | 300.6 mg/l    |
| Fe                | 21.5 mg/l     |
| Mg                | 109.44 mg/l   |
| pH                | 7.6           |
| conductivity      | 1073 mS/m     |

The highest concentration of nitrogen and humic substances that represent main locality contaminants is connected with PN-1, PN-2 and PN-3 boreholes area, i.e. surrounding of shallow backfill aquifer. Concentration of humic substances exceeded 1000 mg/l and of ammonium ions exceeded 10 mg/l in the past. At the present, concentration of humic substances varies from units to first tens of mg/l, occasionally exceeds 100 mg/l. Concentration of ammonium ions decreased to units of mg/l.

Long-term development of humic substances (PN-2) is shown in the following picture, concentrations of selected indicators of ground water (PN-2) are stated in following table.

![Figure 2. Long-term development of humic substances in groundwater (PN-2).](image)

Character of backfill shallow water is influenced by increased surface rainfall recharge in the area of PN-1, PN-2 and PN-3 boreholes. It was observed via water temperature changes. The temperature varies from 6 to 25 degrees of Celsius with maximum level in July and minimum in April. Temperature of quaternary aquifer is more balanced and ranges from 9 to 14 degrees centigrade. From the long-term point of view we can observe declining concentration of almost all indicators in shallow water except for HCO₃⁻ and pH. Occasionally increased values of primary contaminants can be observed in connection with higher precipitation.
Humic substances almost do not occur in groundwater of quaternary aquifer. Only occasionally its concentration exceeds 10 mg/l. In the contrary, high content of ammonium ions occurs in quaternary aquifer. Its level is commonly around units of mg/l, locally about 10 mg/l (PK-2 borehole). Chemism change of the quaternary aquifer can signal degradation of humic substances whose partial degradation of side chains can cause the appearance of ammonium ions. Ammonia nitrogen is final product of mineralization of the plant matter. Further in the direction of the ground water flow, ammonia ions are subject of nitrification in oxidizing environment.

| Date       | Concentration [mg/l] | Date       | Concentration [mg/l] | Date       | Concentration [mg/l] | Date       | Concentration [mg/l] |
|------------|----------------------|------------|----------------------|------------|----------------------|------------|----------------------|
|            | Cl^−                 | HCO_3^−    | N-NH_4                | N-org      | Humic s.              |            |                      |
| 27.4.2010  | 340                  | 945        | 60.2                  | 65.5       | 4320                 | 27.4.2010  | 340                  | 945        | 60.2                  | 65.5       | 4320                 |
| 5.4.2011   | 70                   | 378        | 8.7                   | 9.53       | 282                  | 5.4.2011   | 70                   | 378        | 8.7                   | 9.53       | 282                  |
| 11.4.2012  | 132                  | 752        | 13.7                  | 33.6       | 1070                 | 11.4.2012  | 132                  | 752        | 13.7                  | 33.6       | 1070                 |
| 15.4.2013  | 189                  | 922        | 10.3                  | 25.4       | 1720                 | 15.4.2013  | 189                  | 922        | 10.3                  | 25.4       | 1720                 |
| 2.4.2014   | 45.2                 | 595        | 0.76                  | 7.1        | 63.9                 | 2.4.2014   | 45.2                 | 595        | 0.76                  | 7.1        | 63.9                 |
| 13.4.2015  | 87.8                 | 846        | 14.2                  | 30.6       | 347                  | 13.4.2015  | 87.8                 | 846        | 14.2                  | 30.6       | 347                  |
| 21.4.2016  | 136                  | 444        | 19.5                  | 19.7       | <1.0                 | 21.4.2016  | 136                  | 444        | 19.5                  | 19.7       | <1.0                 |

5. Conclusions
There are two hydraulic systems, backfill and quaternary aquifer in the composting plant Točna. General groundwater flow direction of the quaternary aquifer is towards northeast. Within backfill aquifer, the highest groundwater level is situated around the PN-3 borehole where both, backfill and quaternary aquifer, are in contact and there is the occurrence of overflow to rock surrounding due to the increased infiltration.

Nitrogen substances (especially ammonium ions) and humic substances belong among the main groundwater contaminants in the interest area. Maximum concentration level of these substances is located around the PN-1, PN-2, PN-3, PK-1 and PK-2 boreholes, i.e. at the southeast and east edge of the composting plant locality. According to long-term results of groundwater monitoring, there is gradual reduction of observed concentrations, especially in the water of backfill layer. The influence on the quality of quaternary aquifer is not distinct, just in particular spots situated in the contact of both aquifers (PK-1 and PK-2) where ammonium ions are increased (decomposition of the humic substances). The observed substances almost do not disseminate in the quaternary aquifer. The amount of water leaking onto to terrain surface is distinctly limited by the hydraulic barrier (groundwater pumping in PN-1 borehole).

It is obvious that the situation in situ has gradually been stabilizing which is considerably supported by drier weather conditions in recent years. Thanks to implementation of the technical measures, there is no further groundwater pollution. We can observe gradual improvement of the groundwater quality in the rock surroundings.

6. Acknowledgments
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7. References
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