Lehr- und Forschungszentrum für Landwirtschaft
Raumberg-Gumpenstein

15. Gumpensteiner Lysimetertagung 2013, 195 – 198
ISBN: 978-3-902559-90-6

Determination of water balance components with high precision weighing lysimeter in Klece

Vesna Zupanc[1*], Reinhard Nolz[2], Peter Cepuder[2], Branka Bracic-Zelecznik[3] and Marina Pintar[1]

Summary
Components of the basic water balance equation and water balance calculation for three summer months, June, July and August 2011 for weighing lysimeter on the water supply pumping station in Kleče, Ljubljana were evaluated. Lysimeter and outflow mass were measured with high precision weighing cells. Precipitation measurements in the same time resolution as the lysimeter mass measurements would be needed for proper calculation of reference evapotranspiration. In time of high plant water requirements only substantial precipitation events directly contributed to water flow from top soil toward deeper layers of the lysimeter after the soil retention capacity was filled. The low water retention of the aquifer sediments shows susceptibility of the aquifer to ground water pollution.

Keywords: groundwater recharge, infiltration, deep percolation

Introduction
Soil percolate from precipitation provides important recharge to groundwater. Measurements of water percolation through the vadose zone provide important input for groundwater recharge assessments and estimations of contaminant migration from land surface to the groundwater (RIMON et al. 2007). Knowledge of the processes governing groundwater recharge in the vadose zone is critical to understanding the overall hydrological cycle and quantifying the links between land uses and groundwater. Ljubljansko polje ("Ljubljana field") aquifer is replenished through precipitation and the snow-rain flow regime of the River Sava, which is the main source of groundwater recharge beside precipitation (VIŽINTIN et al. 2009). The sediments of the aquifer have high porosity and create fast flow as well as high regeneration of the dynamic reserve of the Ljubljansko polje groundwater (VIŽINTIN et al. 2009). In the presented paper the potential for groundwater recharge was evaluated through water balance parameters.

Material and methods
In 2010 a scientific weighing lysimeter (2 m height, surface area 1 m²) was installed at the drinking water pumping station in Ljubljana Kleče, Slovenia (308 m altitude, 46°5'11'' N, 14°29'56'' E) for water balance studies of the Ljubljana aquifer's vadose zone (ZUPANC et al. 2012). Inside the monolith soil water tension (hPa) and soil water content (%) are measured on three (50, 100 and 150 cm) and four (50, 100, 150 and 190 cm) levels, respectively. Lysimeter's plant cover is extensive grass. The soil monolith was taken from sandy gravel sediments on the area of the water pumping station, which are representative of Ljubljansko polje. Soil profile is heterogenous, top soil with high percentage of silt particles extends to 130 cm, with gravelly layer in the middle (*Table 1*).

Components of the basic water balance equation for the lysimeter are precipitation (P), outflow (O), evapotranspiration (ET) and change of water in the monolith (ΔS), written as

$$P - ET - O - \Delta S = 0 \qquad (1)$$

If the lysimeters' mass is recorded in certain time steps, with precipitation and outflow amount measured separately, actual evapotranspiration can be deduced from their mass change (YOUNG et al. 1996). ET_a should then be calculated after

$$ET_a = (P_{i+1} - P_i) - (W_{i+1} - W_i) - (O_{i+1} - O_i), \qquad (2)$$

where ET_a is actual evapotranspiration (mm), P_i precipitation (mm), W_i lysimeter mass (kg) and O_i mass of the outflow tank (kg), i is the time step. All quantities should have the same temporal resolution. Parameters were determined on a daily base using Eq. 2, with i being 24hrs. P was determined directly from the lysimeter weighing data (P_{lys}). Weighing lysimeters with the same precision have given

Table 1: **Soil particle fractions (%), bulk density and porosity for weighing lysimeter in Kleče, Ljubljana, Slovenia**

Depth (cm)	Clay	Silt	Sand	Gravel > 4 mm	Bulk density (g/cm³)	Porosity
0-35	5.0	57.5	15.3	22.2	1.40	47.1
35-60	1.0	10.0	14.6	74.4	1.61	39.2
60-130	5.0	35.0	14.8	45.2	1.57	40.6
130-200	0.0	0.0	13.3	86.7	1.86	29.9

[1] University of Ljubljana, Biotechnical faculty, p.p. 2995, SI-1001 LJUBLJANA
[2] University of Natural Resources and Life Sciences, Institute of Hydraulics and Rural Water Management, Muthgasse 18, A-1190 WIEN
[3] Drinking Water and Sewerage System Public Utility, LJUBLJANA
[*] Ansprechpartner: Dr. Vesna Zupanc, vesna.zupanc@bf.uni-lj.si

Table 2: **Daily precipitation P_{lys}, actual evapotranspiration ET_a and outflow dO_{7h} (all in mm) for June, July, August 2011 for weighing lysimeter in Kleče, Ljubljana, Slovenia**

Date	P_{lys} (mm)	ET_a (mm)	dO_{7h} (mm)	Date	P_{lys} (mm)	ET_a (mm)	dO_{7h} (mm)	Date	P_{lys} (mm)	ET_a (mm)	dO_{7h} (mm)
1.6.2011		4.6	0.5	1.7.2011		2.5	1.8	1.8.2011	0.4	3.9	1.1
2.6.2011	5.0	2.0	0.1	2.7.2011	6.2	3.2	1.6	2.8.2011		2.9	0.8
3.6.2011	1.8	3.8	0.6	3.7.2011		3.9	0.6	3.8.2011	0.1	4.3	0.9
4.6.2011	9.1	2.6	-0.5	4.7.2011		4.4	1.5	4.8.2011		4.4	0.7
5.6.2011	7.2	2.2	-1.0	5.7.2011		5.4	2.6	5.8.2011	4.0	3.9	0.5
6.6.2011	11.8	1.5	2.6	6.7.2011	7.7	3.1	1.2	6.8.2011		3.6	0.5
7.6.2011	0.1	2.0	1.8	7.7.2011		4.7	0.9	7.8.2011		3.1	0.4
8.6.2011	56.3	1.1	1.8	8.7.2011		5.0	0.8	8.8.2011		4.4	0.4
9.6.2011	8.6	3.3	22.3	9.7.2011		5.3	0.7	9.8.2011	17.2	2.3	0.6
10.6.2011	13.8	1.2	7.6	10.7.2011		5.3	0.7	10.8.2011	2.7	2.1	0.5
11.6.2011		4.2	14.1	11.7.2011		5.2	0.7	11.8.2011	0.1	3.1	0.4
12.6.2011		4.1	5.4	12.7.2011		4.8	0.5	12.8.2011	0.1	3.5	0.5
13.6.2011	1.5	2.7	3.0	13.7.2011		4.2	0.6	13.8.2011	0.1	3.5	0.4
14.6.2011		3.1	2.3	14.7.2011		4.5	0.3	14.8.2011	0.1	3.7	0.5
15.6.2011		2.7	1.5	15.7.2011		4.3	0.4	15.8.2011	0.1	3.6	0.4
16.6.2011		4.6	1.3	16.7.2011	9.0	1.3	0.4	16.8.2011	0.1	3.1	0.4
17.6.2011		4.4	1.1	17.7.2011		4.0	0.4	17.8.2011	0.1	3.4	0.4
18.6.2011	7.0	1.7	0.8	18.7.2011	31.0	3.7	0.2	18.8.2011	0.1	3.5	0.3
19.6.2011	17.5	4.4	0.8	19.7.2011	6.9	2.6	0.3	19.8.2011	0.1	3.6	0.5
20.6.2011	7.0	0.5	0.6	20.7.2011	1.8	3.5	0.3	20.8.2011	2.1	3.4	0.4
21.6.2011	0.1	3.9	0.5	21.7.2011	6.7	2.2	0.2	21.8.2011	0.1	3.6	0.4
22.6.2011		5.0	-0.7	22.7.2011		5.8	0.3	22.8.2011	0.1	3.4	0.5
23.6.2011		5.1	-3.1	23.7.2011	16.3	3.7	0.3	23.8.2011	0.1	3.4	0.4
24.6.2011	16.9	4.1	0.3	24.7.2011	146.2	1.2	3.8	24.8.2011		3.5	0.4
25.6.2011	6.7	0.2	1.1	25.7.2011	11.4	3.9	64.1	25.8.2011		3.5	0.5
26.6.2011		4.1	-0.4	26.7.2011		3.3	32.4	26.8.2011		3.3	0.4
27.6.2011		3.3	-3.4	27.7.2011	0.2	4.0	5.0	27.8.2011		3.2	0.5
28.6.2011		4.9	1.5	28.7.2011	4.5	4.2	3.1	28.8.2011	7.9	2.7	0.4
29.6.2011		4.7	1.3	29.7.2011	0.6	1.4	2.1	29.8.2011		2.5	0.4
30.6.2011		5.5	1.1	30.7.2011	1.7	2.7	1.4	30.8.2011		2.9	0.4
				31.7.2011	2.3	1.8	1.4	31.8.2011	0.4	2.7	0.4
Sum	170.4	97.5	64.8		252.5	115.5	131.0		35.6	103.8	15.4

good results for dew measurements (MEISSNER et al. 2007, XIAO et al. 2009), and they deliver proper results if *P* from standardized pluviographs is not representative (remote location), malfunctioning or inadequate in terms of temporal resolution of measurements. The ratio between effective precipitation and outflow was determined. The objective was to determine basic water balance parameters for weighing lysimeter in Kleče, Ljubljana, Slovenia for June, July and August in 2011.

Results and discussion

June 2011 had wet first decade (113.8 mm from 2nd - 10th June), which was followed by substantial outflow from 9th to 16th of June (57.5 mm) that amounted to 50 % of the storm water that reached the lysimeter's surface (*Table 2*). In spite of several ensuing precipitation events, the next significant outflow event was at the end of July (24th of July - 1st of August, 114.5 mm), following heavy precipitation on 23rd - 25th of July 2011 (173.9 mm). The outflow amount was over 63.8 % of the storm water (ZUPANC et al. 2012). August 2011 was mostly dry with 35.6 mm of rain and 15.4 mm of outflow. Average daily actual evapotranspiration in June, July and August was 3.2, 3.7 and 3.3 mm per day, respectively; monthly actual evapotranspiration was the highest in July (115.5 mm) and the lowest in June (97.5 mm).

Even though precipitation in both June and July was above 1961 - 1990 average (157 mm and 120 mm for June and July, respectively), water balance was only slightly positive (*Table 3*). Precipitation in August 2011 (35.6 mm) was below 30yr average, which is 141 mm, and water balance was strongly negative, −83.2 mm (*Table 3*). Monthly ratio between the amount of monthly outflow and monthly precipitation was the lowest in June (0.38) and the highest in July (0.52, *Table 3*).

In the evaluated three summer months only substantial precipitation events, or prolonged periods with precipitation resulted in significant outflow. High outflow amount to the lower layers that has potential to recharge the groundwater

Table 3: **Precipitation, actual evapotranspiration, outflow, water balance (all in mm) and outflow/precipitation ratio for June, July, August 2011 for weighing lysimeter in Kleče, Ljubljana, Slovenia**

	June	July	August
Precipitation (mm)	170.5	252.7	35.6
Actual evapotranspiration (mm)	97.5	115.5	103.8
Outflow (mm)	64.8	131.0	15.4
Water balance (mm)	8.3	6.3	-83.2
Ratio Outflow / Precipitation	0.38	0.52	0.43

occurred twice, once at the beginning of June and once at the end of July. In hotter and dryer periods, such as was the case in the third decade of June and first two decades of July, precipitation water only replenished the top soil layers. The silty top soil layer in the lysimeter has good water retention capabilities; however, once the water has percolated through it, the retention of the gravelly layer is quite low.

Conclusions

Only substantial precipitation events, or prolonged periods with precipitation resulted in significant percolation to lower layers, which has potential to recharge the groundwater. In hotter and dryer periods precipitation water only replenishes the top soil layers and is presumably used for plants' needs.

Acknowledgements

This work was partly funded by OeAD and Slovenian Research Agency in bilateral cooperation project BI-AT 11-12-024 – Comparison of data management for selected lysimeter stations in Slovenia and Austria.

Literature

MEISSNER, R., J. SEEGER, H. RUPP, M. SEYFARTH and H. BORG, 2007: Measurement of dew, fog, and rime with a high precision gravitation Lysimeter. Journal of Plant Nutrition and Soil Science, 170, 335-344.

VIŽINTIN, G., P. SOUVENT, M. VESELIČ and B. ČENČUR CURK, 2009: Determination of urban groundwater pollution in alluvial aquifer using linked process models considering urban water cycle. Journal of Hydrology, 377, 3-4: 261-273.

VON UNOLD, G. and J. FANK, 2008: Modular Design of Field Lysimeters for Specific Application Needs. Water Air Soil Pollut: Focus 8: 233-242.

XIAO, H., R. MEISSNER, J. SEEGER, H. RUPP and H. BORG, 2009: Effect of vegetation type and growth stage on dewfall, determined with high precision weighing lysimeters at a site in northern Germany. Journal of Hydrology 377: 43-49.

YOUNG, M.H., P.J. WIERENGA and C.F. MANCINO, 1996: Large weighing lysimeters for water use and deep percolation studies. Soil Science, 161: 491-501.

RIMON, Y., O. DAHAN, R. NATIV and S. GEYER, 2007: Water percolation through the deep vadose zone and groundwater recharge. Water Resources Research. 43, 5, 1-12.

ZUPANC, V., R. NOLZ, P. CEPUDER, B. BRAČIČ-ŽELEZNIK and M. PINTAR, 2012: Determination of water balance components with high precision weighing lysimeter Kleče. Acta agric. Slov. Vol. 9, 2, 165-173.