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Water balance assessment for lysimeter station based on Water Pumping Station Kleče in Ljubljana

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ABSTRACT

For soil water balance calculation two lysimeters were built on Water Pumping Station of Public Water Supply Company in Ljubljana. Soil water balance (change in storage) was calculated using precipitation, evapotranspiration, and lysimeter outflow. Outflow measurements systematically showed discrepancy between Lysimeter North and Lysimeter South, in average 300 mm/year. Yearly soil water balance calculation for the Lysimeter North shows slight decrease in water storage every year in studied period (2001 – 2004).

Key words: lysimeter, water balance

IZVLEČEK

OCENA VODNE BILANCE ZA LIZIMETRSKO POSTAJO PRI VODARNI KLEČE V LJUBLJANI

Na črpališču Kleče javnega podjetja Vodovod-Kanalizacija Ljubljana sta bila zgrajena dva lizimetra za ugotavljanje vodne bilance tal. S pomočjo padavin, evapotranspiracije in iztoka iz lizimetra smo izračunali vodno bilanco tal (spremembo v zalogi vode v tleh). Meritve iztoka iz lizimetrov so pokazale razliko med severnim in južnim lizimetrom, v povprečju 300 mm na leto. Izračun vodne bilance na letni ravni za severni lizimeter nakazuje rahlo zmanjšanje v zalogi vode v tleh za vsako leto v opazovanem obdobju (2001 – 2004).

Ključne besede: lizimeter, vodna bilanca

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1 INTRODUCTION

Water is the solvent that moves many of the chemicals (nutrients and pesticides) from agricultural fields to offsite locations. This offsite movement causes much concern in terms of consequences on the quality of drinking water and the impact of agricultural practices on the environment. Water movement can contribute to offsite impacts in two ways. First is leaching through the soil profile and the second is surface runoff. In order to understand and determine the optimal management possibilities, the water balance must be considered as a year-round process and not only during the growing season. While components of the water balance are in a continuous state of flux, the spatial and temporal variation of these components are very complex.

The water balance is defined by the general hydrologic equation, which is basically a statement of the law of conservation of mass as applied to the hydrologic cycle (Ridder and Boonstra, 1994). The general equation of the soil-water budget is derived by considering the mechanisms by which water can enter, exit, or be stored in a predefined region of the vadose zone (Stephens, 1995). Water balance equations can be assessed for any area and for any period of time (Ridder and Boonstra, 1994). Water balance for unsaturated zone is determined by equation

$$I - ET + C - R = \Delta S / \Delta t \quad (1)$$

where I is the rate of infiltration into the unsaturated zone (mm/day), ET evapotranspiration (mm/day), C capillary rise from saturated zone (mm/day), R the rate of percolation to the saturated zone (mm/day), ΔS the change in soil water storage in the unsaturated zone during the computation interval of an equivalent layer of water (mm), Δt the computation interval of time (day).

Ljubljana, the capital of Slovenia, lies in the area rich with both surface and groundwater. Two aquifers, Ljubljansko polje and Ljubljansko barje, represent drinking water resources for almost 300.000 inhabitants. The major part of the vulnerable Ljubljansko polje aquifer, which provides water supply for the 90% of the whole population lies beneath urban and agricultural areas (Jamnik et al., 2003). Two recharging components of the Ljubljansko polje groundwater, i.e. the local precipitation and infiltrated Sava river are exposed to different sources of contamination because they originate from different parts of hydrological circle. Direct infiltration of precipitation makes the aquifer vulnerable to contamination by pollutants flushed through soils (Jamnik et al., 2003).

In order to understand the all – year mechanisms that govern the water balance components, two lysimeters were built in 1991 on the water pumping station of Water and Waste Water Public Utility Supply in Ljubljana, Slovenia. Active measurements of precipitation and lysimeter outflow were reinstated in August 2000. The purpose of this paper is to overview and analyze the existing measurement results from the year 2000 to 2004 as well as to determine the data reliability.

2 MATERIALS AND METHODS

2.1 Materials

Lysimeter station in Kleče, Ljubljana is situated in the area of the main Water Pumping Station of Water and Waste Water Public Utility Supply of the city on the alluvial plain of Ljubljana field. Agricultural fields surround the Water Pumping Station. Daily measurements of rain, air humidity, average air temperature and lysimeter outflow are measured. Input data are meteorological parameters from the meteorological station located 2 km of aerial distance from the Water Pumping Station.

Lysimeters (180 cm diameter, 200 cm depth) are filled with autochthon soil, sand, gravel and drainage material in 50 cm layers respectively. From the drainage material layer outflow drain leads into bunker. Lysimeter vegetation is extensive green grass. Out flow is measured with tipping bucket in a container inside the bunker (Figure 1).

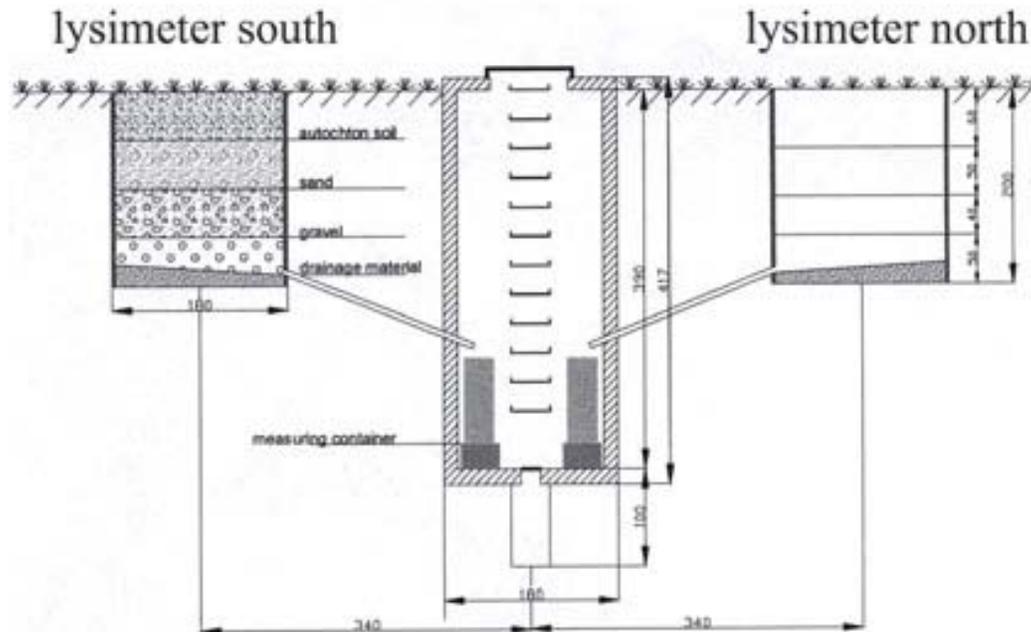


Figure 1: Lysimeter station profile on Water Pumping Station of Water and Waste Water Public Utility Supply in Kleče, Ljubljana.

2.2 Methods

With the assumption that the water flow is mainly vertical and no lateral flow components occur, water balance for lysimeter is defined with equation

$$P - ET - O = \Delta S, \quad (2)$$

where P is precipitation, ET evapotranspiration, O outflow and ΔS change in soil water storage inside the lysimeter.

For P measurements from meteorological station were used. Evapotranspiration ET was calculated using Penman - Monteith equation (Monteith, 1965). For O outflow water quantity measurements conducted by tipping bucket system installed in the lysimeter bunker (Figure 1) were used.

Water outflow O measurements showed enormous quantity discrepancies between the two lysimeters. Therefore a careful examination of the construction employing video camera was

carried out. Additional experiment with adding an exact amount of water was conducted after a dry period of 30 days to determine what could be causing the difference.

3 RESULTS AND DISCUSSION

The average annual precipitation measured on the lysimeter station is 1083 mm, with the average monthly temperature of 12°C (Figure 2). In observed period 2000 – 2004 the maximum driest month March in 2003, the maximum wettest November 2000. Summer's driest month was August.

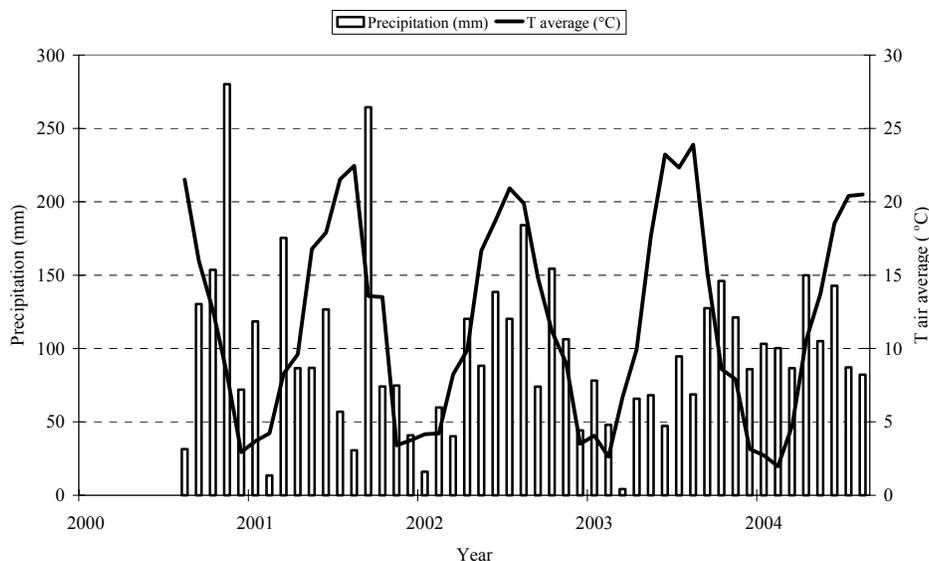


Figure 2: Monthly precipitation (mm) and average air temperature (°C) for Lysimeter station on Water Pumping Station of Public Water Supply Company in Kleče, Ljubljana 2000 – 2004

Average evapotranspiration (ET) rate calculated Penman – Monteith equation was 70 mm per month. Average cumulative ET in vegetation period (beginning of April – end of September) was 630 mm and total annual ET was 800 mm per year (Figure 3).

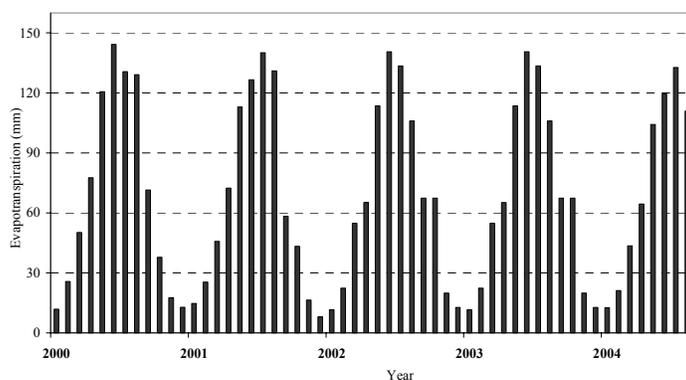


Figure 3: Monthly evapotranspiration (mm) for Ljubljana in the studied years 2000 – 2004

Lysimeter outflow quantity comparison between Lysimeter North and South showed outflow from the Lysimeter South to be considerably smaller (in average 85 mm/year) from the outflow from Lysimeter North (in average 386 mm/year) (Figures 4 and 5).

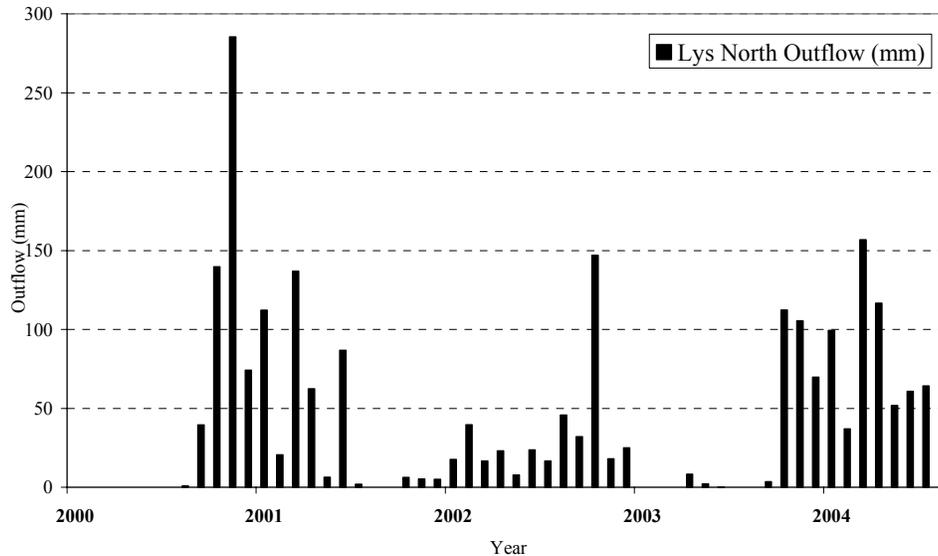


Figure 4: Monthly outflow (mm) for Lysimeter North, Lysimeter station on on Water Pumping Station of Public Water Supply Company in Kleče, Ljubljana 2000 – 2004 (marks noting the beginning of the year).

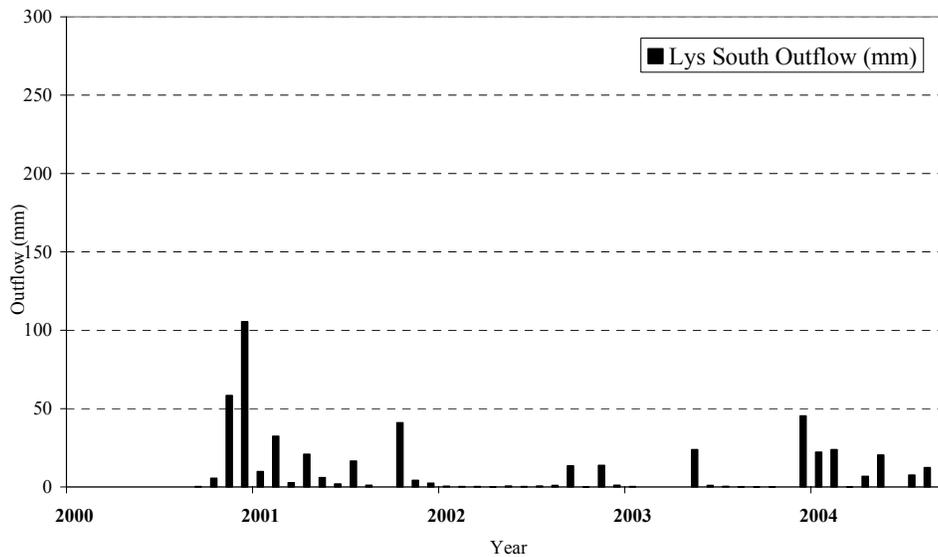


Figure 5: Monthly outflow (mm) for Lysimeter South, Lysimeter station on Water Pumping Station of Public Water Supply Company in Kleče, Ljubljana 2000 – 2004 (marks noting the beginning of the year).

Vegetation cover comparison between the two lysimeters showed no sign of soil becoming marshy or change in vegetation on the Lysimeter South, therefore outflow clogging has been ruled out. Special camera for piping system function monitoring

attached to a wire was applied. Video overview showed functioning pipe without cracks or sediments till the gravely material inside the lysimeter (at the depth of app. 200 cm, Figure 1). The video overview and vegetation cover lead to the conclusion that the difference in outflow quantity could be contributed to the crack in the lysimeter construction. To verify this hypothesis a known amount of water was added to the Lysimeter North and South at the same time with simultaneous outflow measurements. This experiment was conducted in March 2003 after 30 days without precipitation, where out of 120 l of added water on the 28th of March 2003, the Lysimeter North returned 97.4 l and Lysimeter South 29.8 l over the following week. Therefore, due to the unreliable outflow results from the Lysimeter South, the latter was excluded from further observation.

Using the equation (2) monthly (Figure 6) and yearly (Figure 7) change in storage ΔS for the Lysimeter North was calculated for the studied years 2000 – 2004. Monthly change in storage shows slight inclination toward negative budget. Year 2000 (measurements from August to December) showed strong negative balance, which continued throughout the year 2001 (–100 mm in summer months June – August) till the month of September where it turned strongly positive (+206 mm). Change in storage ΔS was positive twice in the year 2002, in the months of April and August (+32 mm) as well as in winter (in November +70 mm and +6 mm December). Otherwise it was negative from –10 to –60 mm per month. Year 2003 began with positive ΔS but then with the exception of September it showed negative balance most noticeably in the month of June (–90 mm). Year 2004 had strong ΔS in March +113 mm and in July +110 mm with small positive in February (+40 mm).

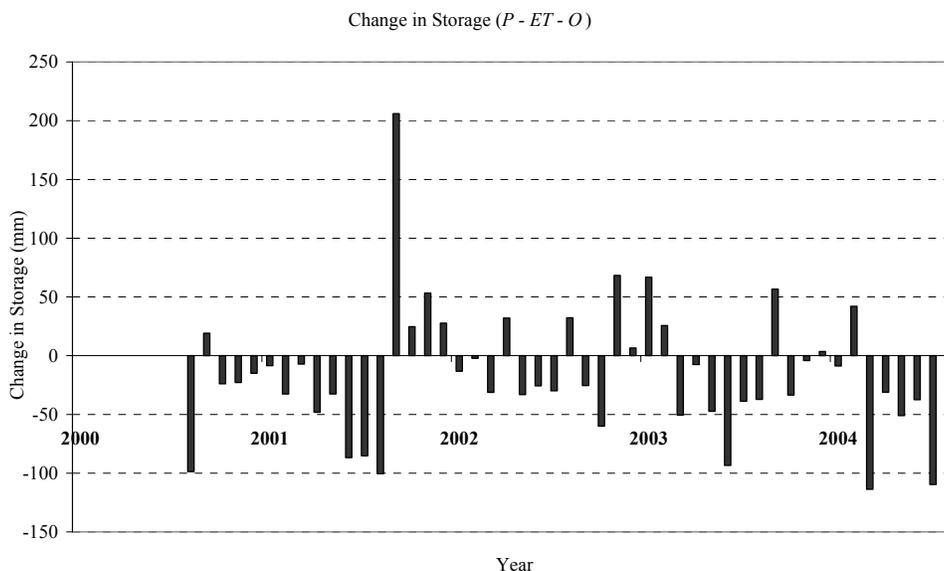


Figure 6: Monthly change in storage (mm) for the Lysimeter North, Lysimeter station on Water Pumping Station of Public Water Supply Company in Kleče, Ljubljana 2001 – 2004 (marks noting the beginning of the year).

Yearly soil water balance for the Lysimeter North shows slight decrease in water storage every year (Figure 7), from –89 mm per year in 2001, –60 mm per year in 2002 to –171 mm per year in 2003.

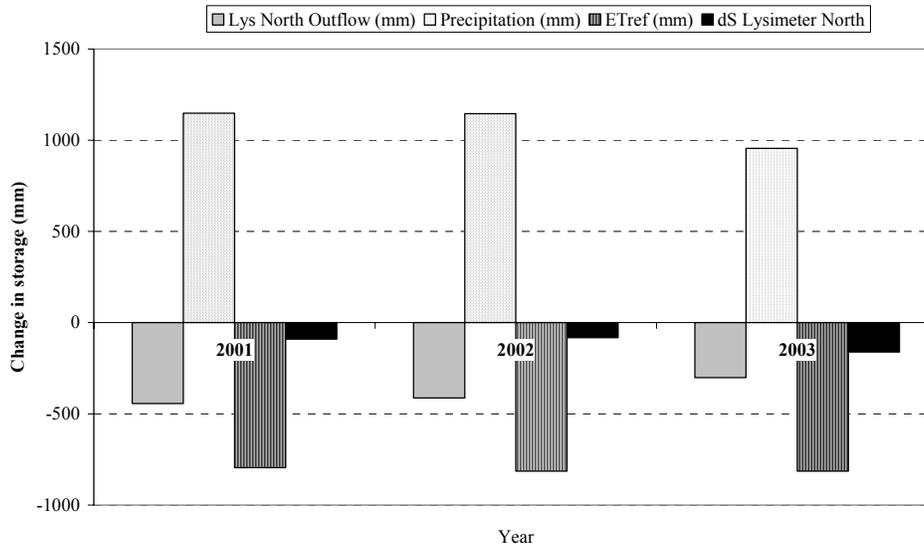


Figure 7: Annual soil water balance elements for Lysimeter North, Lysimeter station on Water Pumping Station of Public Water Supply Company in Kleče, Ljubljana 2001 – 2003

4 CONCLUSIONS

The average annual precipitation measured on the Lysimeter station on Water Pumping Station of Public Water Supply Company in Kleče, Ljubljana is 1083 mm. Evapotranspiration calculated after Penman – Monteith is 800 mm per year.

Lysimeter outflow quantity comparison between Lysimeter North and South showed outflow from the Lysimeter South to be considerably smaller (85 mm/year) from the outflow from Lysimeter North (386 mm/year).

After thorough examination it was concluded that there is a rupture on the Lysimeter South construction.

Monthly and yearly water balance calculation for the Lysimeter North for the years 2001 – 2003 shows slight inclination toward negative budget. The change in storage ranges from –89 mm per year in the year 2001, –60 mm per year in 2002 to –171 mm per year in 2003.

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