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GROUNDWATER SOURCE PROTECTION IN SLOVAK REPUBLIC

ABSTRACT

Groundwater represents more than 80 % of potable water consumption in Slovakia. Our biggest reservoir of high quality potable groundwater is located on Žitný Island (Rye Island) in Slovak Republic. This region represents only 3.5 % of Slovakia whole acreage, nevertheless on this island is located 35% of whole groundwater reserve. Not only this groundwater source, but also many other in Slovakia are situated in locations with hospitable conditions for plant production. Each groundwater source, dedicated to supply inhabitants with potable water, has legislatively defined protective zones. Protective zones of ground water sources, according to small acreage of agricultural soil fall on 1 inhabitant in Slovakia and big amount of sources protective zones, cannot be isolated from agriculturally used land. Plant production in those zones has to adapt to groundwater source protection requirements. Based on groundwater source protection scientific analyses, we had to determine the most suitable plants for actual protective zone, find the most suitable agrochemical and size of its dosages and terms of applications. This paper analyse methods of groundwater source protection zones utilization in Slovak Republic.

Keywords: groundwater source, protection zones, water.

INTRODUCTION

Groundwater represents more than 80 % of potable water consumption in Slovakia. Our biggest reservoir of high quality potable groundwater is located on Žitný Island (Rye Island) in Slovak republic. This region represents only 3.5 % of Slovakia whole acreage, nevertheless on this island is located 35% of whole groundwater reserve of which is able to use more than 20 $m^3.s^{-1}$. This region is not only one the most important potable water reservoirs but also region with very good natural conditions for plant production. Not only this location but also many other groundwater sources in Slovak republic are localized in areas with favourable natural conditions for plant production. Least amount of groundwater sources are localized in eastern part of Slovakia (Noskovič, 2003). According to relative small acreage of agricultural soil falling on 1 inhabitant of SR (0,44 ha)

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and according to large amount (more than 1100) and size of protection zones (almost 20% of Slovakia acreage) cannot be protective zones excluded from agricultural utilization. Plant production in protective zones has to adapt to water source protection requests, it means that we have to ensure plant production management for actual protection zone which will endanger the quality of groundwater sources before its contamination from agriculture, as few as possible. It means that we have to identify the most suitable plants, agrochemicals, dosage of agricultural chemicals and terms of its application. By means of mentioned we can in some cases decrease groundwater pollution.

MATERIAL AND METHODS

Basis for the resolution of this issue were background results of experimental and theoretical works, accomplished by employees of Department of Biometeorology and Hydrology of SUA in Nitra (e.g. Antal 1976, 1977, 1980, 1990, Antal et al. 2006, 2009, 2014, Tóthová 2008). Results of soil solution movement modelling, by means of model MOVOREP (Benetin et al, 1985.) were used for scientifically justified choice of appropriate plants in actual groundwater protection zone and for determination of most suitable periods for agrochemicals application (primarily for nitrogen fertilization). The result of soil solution movement solving with model MOVOREP is also so called water equivalent zone, defined by equation (Antal et al., 1984):

$$WEZ = \frac{W_j}{1000.\Theta_{FC}} \quad (1)$$

where:
WEZ - water equivalent zone in j- time interval of vegetation period [m],
W_j - soil water storage in j- time interval of vegetation period [mm],
Θ_{FC} - value of soil hydrologic coefficient - field capacity for examined soil profile [$m^3.m^{-3}$].

Soil water storage was counted by means of simplified hydrological balance equation of soil profile:

$$W_j = W_{j-1} + \alpha_{inf}.H_{Z,j} - ET_j \quad (2)$$

where:
α_{inf} - precipitations water infiltration coefficient [-],
$H_{Z,j}$ - depth of precipitations in j- time interval of vegetation period [mm],
ET_j - depth of evapotranspiration in j- time interval of vegetation period [mm].

Soil water storages at the beginning of vegetation period, i.e. time period j=0, are counted in accordance to equation (Benetin et al., 1979- modified):

$$W_O = 0{,}5.\Theta_{FC}.1000 \quad (3)$$

Example of calculated WEZ continuance during vegetation period for winter rye, in years 1951 and 1965 is shown on figure no.1

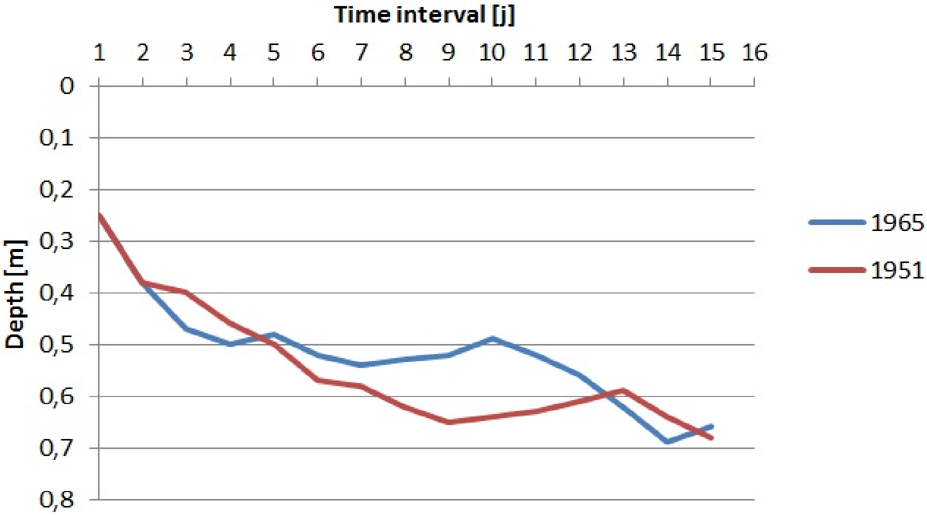

Figure 1: WEZ continuance for winter rye in area Dobrá Niva during years 1951 and 1965.

WEZ value express the location of „piston" in soil profile, above which is located whole soil water storage from root zone of cropped plant. We assume that soil moisture above the „piston", i.e. in WEZ, is equal with the value of soil hydrologic coefficient Θ_{FC} - figure no. 2

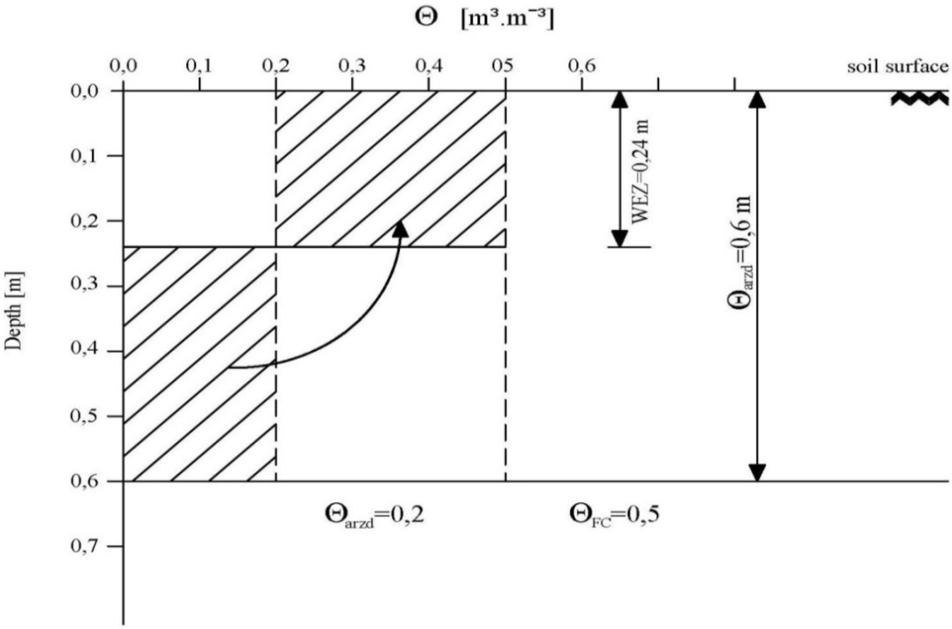

Figure 2: Diagram of WEZ value determination

Input data for WEZ value calculation by means of mathematical hydrologic model MOVOREP are among other climatic and soil characteristics of chosen area following: cropped plants characteristics as daily rainfall totals, average daily air temperatures, soil hydrologic coefficients values, beginning and close of vegetation period for cropped plants and depth of its root zone. Principles of probability theory have to be applied during processing of calculated WEZ values, regarding to fact, that some of those input characteristics have stochastic character. Based on the assumption that until the WEZ value will not exceed value of root zone depth for cropped plant- RZD, i.e. until is valid that $WEZ \leq RZD$ (4), conditions for polluting penetration in to groundwater will not be created till then.

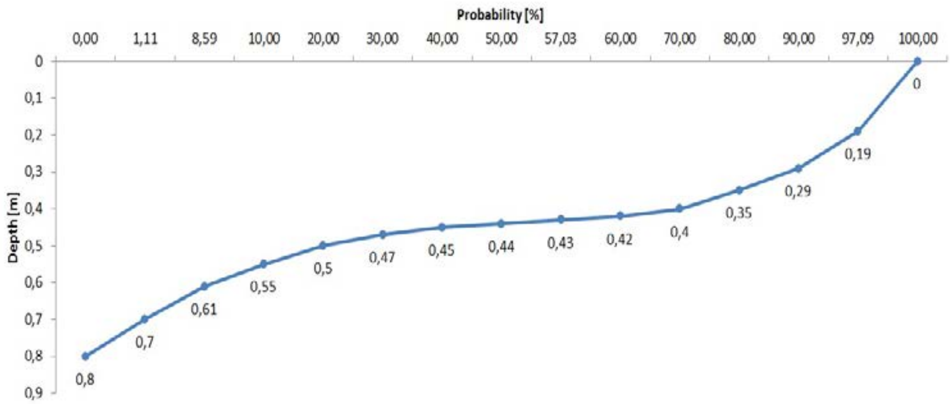

Figure 3: Line of WEZ exceedance during whole vegetation period for winter wheat in area Dobrá Niva in years 1930-1962.

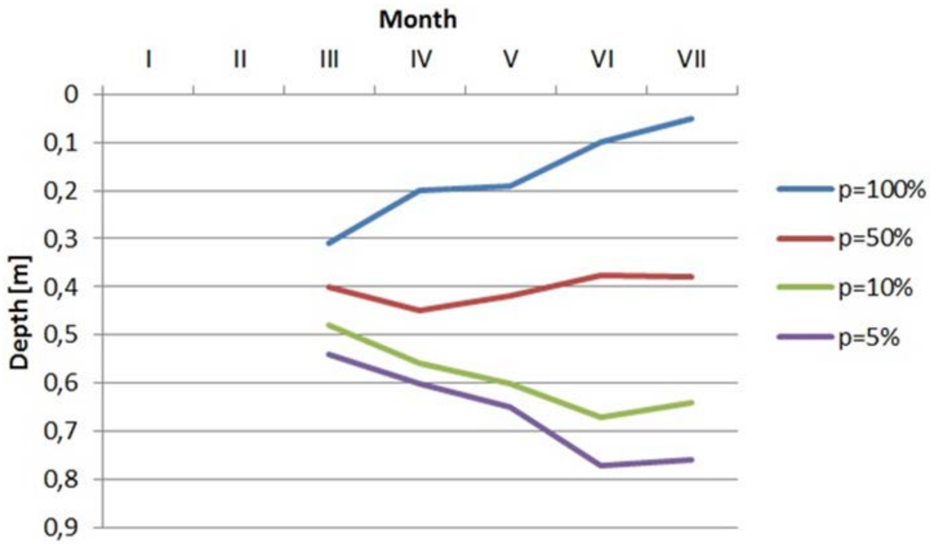

Figure 4: Continuance of WEZ during years 1930-1962 in area Dobrá Niva for winter wheat with occurrence probability p = 5%, 10%, 50% and 100 %

From noted above results that for need of groundwater protection zones proposition utilization is necessary to know so called lines of reaching and exceedance probability for actual groundwater protection zones for cropped plant. Lines of reaching and exceedance probability for certain WEZ value can be constructed for whole vegetation period of cropped plant in actual groundwater protection zone. Actual WEZ continuance with specific probability of occurrence- p can be also constructed.

RESULTS AND DISCUSSION

Examples of graphic relations figuration are shown on illustrations no. 3 and no. 4.

$$WEZ_v^l = f(C, p) \quad (5)$$

$$WEZ_j^{x,l} = f(t, p) \quad (6)$$

where:

WEZ_v^l- value of WEZ^l_v for whole vegetation period of actual locality (l) as a function of cropped plant (C) and probability of its achievement and exceedance (p). [m],

$WEZ_j^{x,l}$- time slope of WEZ value progress with different passage probability by cropped concrete plant in actual GPZ [m].

Graphical expression of relation for all analysed plants (figure no.5) were used for order of plant determination in actual GPZ in accordance to protection level needed and in accordance to active root zone depth (RZD).

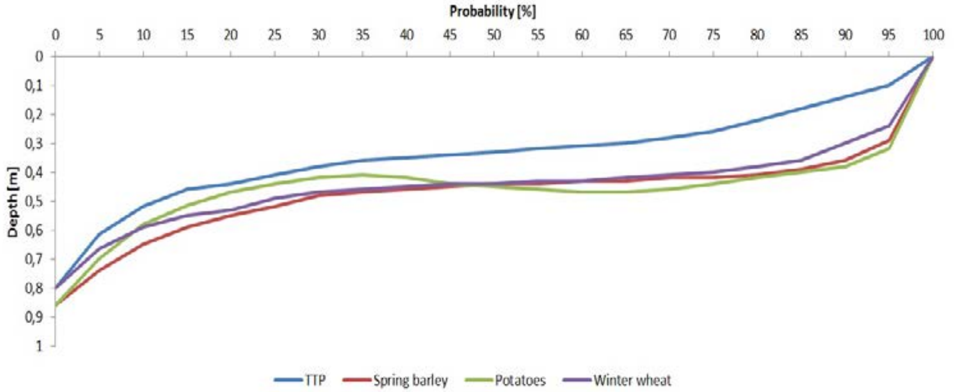

Figure 5: Probability of WEZ exceedance during whole vegetation period for all analysed plants in area Dobrá Niva during years 1930-1962.

From figure no. 5 results that if we want groundwater source protection to be secured with probability p = 100%, than propriety of examined crop order is following: 1. pastures, 2. winter wheat, 3.potatoes, 4. spring barley (the least appropriate plant from water source protection point of view). If we complete graphical expression of relation for actual plant and GPZ with horizontal line which express value of RZD for analysed plant (figure no. 6), then we can use this relation for determination of critical terms for agrochemicals application.

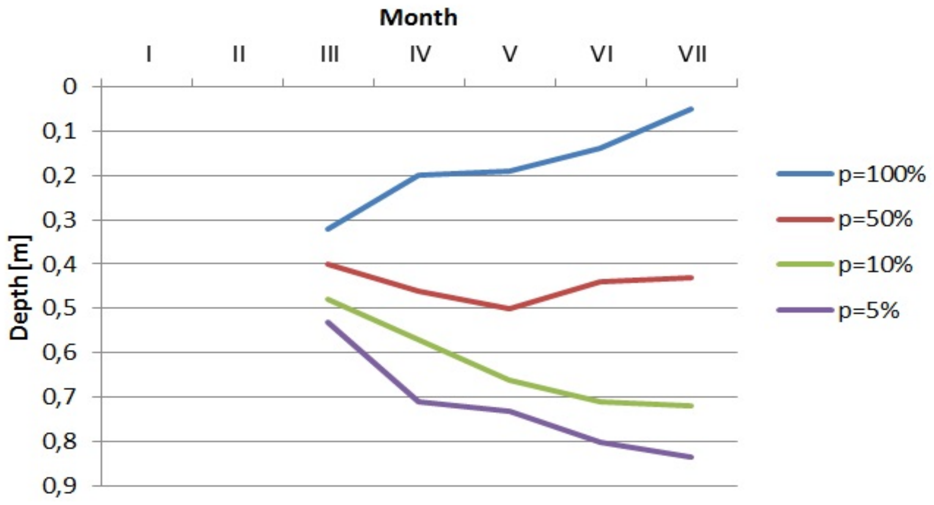

Figure 6. Continuance of WEZ with probability of occurrence p, by planting spring barley.

Based on figure no. 6 is clear that by spring barley cultivation in GPZ Dobrá Niva is not advisable to apply agrochemicals in months from May to July, because of quite big probability of groundwater source pollution, on average once in 10 to 20 years. For comparison on figure no. 7 is shown relation for pastures.

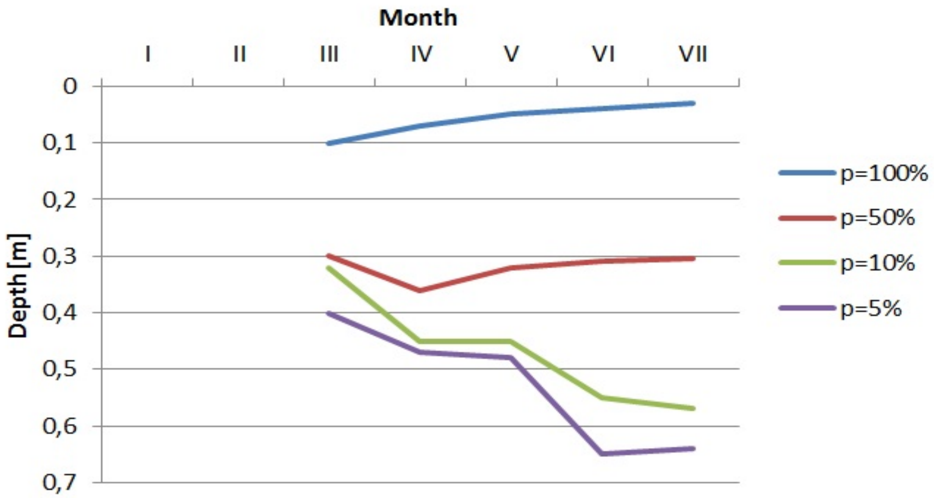

Figure 7: Continuance of WEZ during years 1931-1963 in area Dobrá Niva for pastures with occurrence probability p = 5%, 10%, 50% and 100%.

From this figure is clear that in this GPZ by pastures cultivation is only minimal danger of groundwater source pollution. Pollution is possible on average once in over 20 years.

CONCLUSIONS

Projected way of WEZ utilization for groundwater sources protection means important contribution despite of fact that for WEZ values calculation was used simple model of soil solution movement in soil profile. Its importance is based on possibility to differentiate exactly different stages of groundwater sources protection proposition, possibility to determine exactly the order of plant aptitude for cultivation in actual groundwater protection zone and possibility to determine appropriate and inappropriate periods for agrochemicals application for actual GPZ.

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