Point Irrigation Design for Experimental Field in Northern Part of Gobi Desert in Mongolia

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Abstract: The present paper focuses on the point irrigation design for crops and growing vegetables on an experimental area 2432 m^2 at Buchel locality, Northern part of Gobi desert in Mongolia. An underground water source (drill hole – well capacity 2 l/s with water temperature 10°C) and electricity were available in the locality of the selected area of 1 ha and 0.2% grade of slope (no map was available). The design of the surface and subsurface point irrigation for an area of 128 m^2 is shown together with a brief description of the hydraulic materials used for the development of the original HYBOZAM program, which was programmed in Microsoft Excel editor, especially to design the pipe dimensions of the point irrigation. A combination of two plastic pipes (with diameters 35.4/40 mm and 28.2/32 mm and 20 m lengths each) was used to provide suitable irrigation uniformity from the orifices on the laterals. HYBOZAM program provides a visual evaluation of the discharge distribution uniformity from the orifices on the laterals by its graphical output. An example of Z1 lateral for surface point irrigation (variant 2) is presented. The final result of the design calculation is given in the table presenting the most important outputs, including statistic evaluation of the discharge distribution uniformity. A table is presented for surface point irrigation – variant 2. From the table is it clear that hydraulic requirements as well as discharge distribution uniformity from the orifices on the laterals have been fulfilled.

Keywords: bilateral project; desert; discharge distribution uniformity; Excel; HYBOZAM; hydraulics; PC program; subsurface point irrigation; surface point irrigation; underground water

Design, made by FILIP *et al.* (2007), was created during the bilateral project of developmental cooperation between the Czech Republic and Mongolia "Resumption of Plant Production in Semiarid Regions of Northern Gobi", realisation period 2006–2009. Its submitter was the Ministry of Agriculture of the Czech Republic and its realisation was provided by the Association represented by the Mendel University in Brno. The aim was to design irrigation for the experimental field with crops and vegetables in the selected area of Gobi desert in Mongolia. An underground water source (drill hole – well, capacity 2 l/s, water temperature 10°C), electricity, and a field area of around 1 ha were available at the locality. The requirement was to use a simple irrigation technique; the basic limitation was the impossibility of using any technical or more exacting equipment, e.g. drip irrigation. No maps were available, just an estimation of the slope degree of 0.2% in the flat terrain. The technical design of the experimental surface and subsurface point irrigation is shown together with a brief description of the hydraulic material used for the development of the original HYBOZAM program, which was programmed in Microsoft Excel editor, especially to design the pipe dimensions of point irrigation. It also includes a statistic evaluation of the discharge distribution uniformity from the orifices on the laterals.

MATERIALS AND METHODS

Following information was known and the technical solution was proposed during the project realisation.

Natural conditions

The yearly sum of precipitation at Buchel locality varies between 100–150 mm, approximately 80% (80–120 mm) of which take place during the vegetation period (June–September); it differs from year to year. The summer air temperatures rise up to 21–25°C (maximum up to 40°C). During winters they drop down to –19°C (minimum –36°C). The frost-free period lasts from May to September. An extreme fluctuation of the air temperature in short time intervals may happen during the day. Dust storms appear mainly during March and April and they have a significant desiccation character. Wind blows also during the whole vegetation period, but its speed has not been recorded. It is a typical arid zone, where agricultural farming is not possible without irrigation.

The soil is sandy loam with a high pH value (8 and more). The presence of carbonates is significant mainly in the depth of 0.3–0.5 m. The soil horizon presents a layer of 0.5 m, rarely 0.7 m. Under this is sand or gravel sand. The soil organic matter is low, around 1%, which is typical for arid zones.

Economic conditions

The experimental field includes 3 localities where the agricultural management uses the classical technique of furrow irrigation. The source of the water is a drill well with pumping of 8 h/day. The irrigation on 3 ha is done by estimation and it delivers around 200 m³ of water per day. Washed irrigation regime is probably practiced.

People grow there melons, pumpkins, carrots, tomatoes, cucumbers, garlic, onions, and potatoes.

Irrigation water quality

The basic condition for the success and satisfaction in long term irrigation is a good irrigation water quality. Because the source of irrigation water is the underground water from drill well, which is used as well as drinking water, it is crucial to evaluate the potential danger of soil salinisation and water temperature in such conditions.

According to the provided analyses of the water from drill well, the most often appearing cations are Na^+ 130 mg/l, Ca^{2+} 25 mg/l, and Mg^{2+} 12 mg/l.

To evaluate the irrigation water quality, Sodium adsorption ratio (SAR) was applied which is used abroad for arid climatic zones. Its value for the obtained amount of ions from drill well is 5.4, which shows the water conductance of cca 200 µS/cm, and that means lower salinisation (C1) and low alkalisation (S1). Such a result was presumed by the graph made by Holý *et al.* (1976).

Options of the technical solution

To design an irrigation system, certain limits have to be respected as the degree of water mineralisation of drill well, impracticability of complicated technical irrigation system utilisation, permanent wind containing dust elements, limitation of drill well capacity, water temperature about 10°C, extreme climatic conditions, mainly lower air temperature during winters, field management etc.

Surface point irrigation

The surface point irrigation uses low-pressure polyethylene pipes located on the surface for the water distribution on the plot. These have 2–4 mm orifices. Such a type of irrigation had been used in the Czech Republic in the eighties of the last century, when it was difficult to project the drip irrigation. Home production of the drip irrigation was unreliable and foreign products were expensive.

The advantage of the point irrigation as compared with the drip irrigation is lower requirements for the irrigation water quality which does not demand the construction of, usually, a two-stage filtration plant that is necessary for drip irrigation. The point irrigation disadvantage is a dense pipe irrigation net and the lack of experience with the irrigation of vegetables.

Subsurface point irrigation – subsurface furrow irrigation

The principle of the subsurface irrigation resides in the water supply directly to the crop roots in soil. The subsurface furrow irrigation is created by a system of parallel underground plastic furrows. The cross section of the furrow is 0.3 × 0.2 m and it is located 0.5 m under the surface. A flexible perforated tube was designed in soil near the furrow, which brought water into the furrow. Water is accumulated in the furrow and is spread by capillarity depending on the soil texture to sides and the surface. This type of irrigation was developed and

proven also abroad (former Eastern Germany and Hungary) by Húska and Kabina (1984) with good results. Because it was tested on localities with light soils, it is such a technology recommended also for the desert conditions in Mongolia.

The technology mentioned is relatively demanding for its plastic pipe trench density, thus it is also expensive. The costs are closer to those of the drip irrigation, which is the most expensive technology nowadays.

Hydraulic calculations for microirrigation

From the accessible foreign literature these important findings were gained:

For the correct function of microirrigation, it is necessary for their hydraulic function to pass tests already during their design. Attention must be given above all to the design and function of the laterals. It concerns especially the laterals with drippers without self-regulation, which resemble the point irrigation. The hydraulic calculations needed are accomplished within the programmes developed on PC. Hydraulic calculations of laterals with own programme for PC were presented by Zella *et al.* (2006), whose calculations observed the pressure and discharge on the drippers and as the main criterion for the design of laterals they introduced the optimisation of the discharge uniformity from the drippers placed on the laterals. Yildinm and Agiralioglu (2004) presented a simplified analytical solution for the hydraulic calculation of tapered microirrigation laterals. The analytical solution was created for the linear relationship between the dripper discharge and pressure head. The analytical derivations can be applied for uphill, downhill, and zero slope conditions. Valiantzas (2005) discussed to the calculation method of the previous authors. He stated that the design variables are the lengths and dimension of two given pipes for the laterals as well as the appropriate lengths and dimensions of the available pipes for the manifold. Tapered laterals and manifold are selected in such a way that the sum of the costs of the laterals and the manifold is minimised, while the hydraulic design criterion is ensured. The design procedure can be also applied in sprinkler irrigation. Derong *et al.* (2002) developed a pressure reducing pipe (PRP), used at the inlet of a lateral in microirrigation systems to improve the water application uniformity. The submain unit with the PRP has higher uniformity in laterals than

is that of the commonly used method. The effects of the PRP on the water application uniformity in submain units were analysed by computer simulation. Gerrish *et al.* (1996) presented a method to analyse large microirrigation systems (10 000 drippers or more). The calculations were made on PC using the finite element method and the virtual dripper system without ignoring minor head losses due to the network components. Kang *et al.* (1996) developed a method for designing microirrigation laterals on non-uniform slopes using the finite element method. Six representative non-uniform slope patterns were discussed in detail. The design principle was implemented based on the results of computer simulations. They found out that the diameter of a single lateral or paired laterals may have two solutions for the required uniformity of water application and the length may have multiple solutions. The design procedures are described.

The most important results and findings from our and Slovak literature are presented in the next chapter "Results and discussion", the section "Hydraulic calculation".

RESULTS AND DISCUSSION

The main result is the description of the technical solution designed and hydraulic calculations needed. Irrigation was calculated for the area of 2432 m^2 (60.8 × 40 m).

There were four different irrigation methods for the aforesaid conditions: low-cost point irrigation system in the surface and subsurface (subsurface furrow irrigation) versions, sprinkler irrigation and for comparison classical furrow irrigation was installed, which is widely used in the region.

The surface and subsurface point irrigation has been designed for PE-HD pipes and PN 6 bars service pressure with thinner walls ensuring the hydraulically required inner diameters of pipes. Irrigation water will be pumped from an underground drill well into a tank N1, where it will get warmer and from there it will run by the supply pipeline made by the main line of size 44.2/50 mm, (inside diameter/outside diameter), and submain line of size 44.2/50 mm into perforated laterals from which crops will be irrigated. Point irrigation scheme with partial irrigation block and distribution of laterals on the experimental field for the surface point irrigation and subsurface furrow irrigation is shown in Figure 1.

Surface point irrigation

The laterals designed for PE-HD pipes and PN 6 bars service pressure are placed in partial irrigation blocks. Each block has four laterals in the distance intervals of 0.8 m (Figure 1). The length of the lateral is 40 m, the first upper 20 m being formed by a pipe with the diameter of 35.4/40 mm, the lower 20 m by a pipe with the diameter of 28.2/32 mm. The tubes are equipped with orifices (0.5 m orifice spacing), where the first orifice is 0.25 m distant from the beginning of the pipe. The orifices have 2 mm diameter, and are not covered with a capping strip.

One partial irrigation block will irrigate the area of 3.2 × 40 m = 128 m^2. The eight partial irrigation blocks are located at each side of N1 tank; this represents 16 partial irrigation blocks, that is are 64 laterals all together. The laterals are put down on the surface from the center to both sides in the distance of 5.2 m because the subsurface irrigation is located in the center. It is important to lay the main line with an artificial gradient of 0.2%.

At the beginning of the main line are a filter, a metal ball cock, a water meter and a manometer built. The detailed composition of the surface irrigation system built from pipes and armatures is part of the laying pipe plan in the drawing part of the project (FILIP *et al.* 2007).
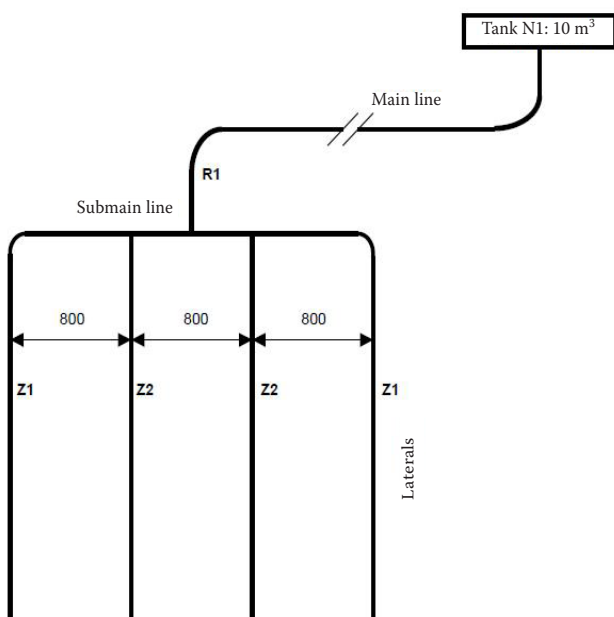

Figure 1. Point irrigation scheme of partial irrigation block with laterals allocation on the experimental plot

Subsurface furrow irrigation

The subsurface point irrigation organised as furrow irrigation has been designed as well for PE-HD pipes and PN 6 bars service pressure. PE-HD material is used also for the laterals watering vegetables, which requires more frequent soil cultivation and thus higher pipes strength to resist an accidental capture by loosing tool.

The laterals have 0.25 m orifices spacing. The orifices have a diameter of 2 mm and are covered with PE-HD capping strip, which is one dimension higher then the perforated pipe. The capping strip length is 80 mm and it is straight-cut.

The laterals are located in the pipe trench 0.5 m deep, 0.3 m wide, and their axis is the distance of 0.8 m. The bottom and walls of the pipe trench will be covered with 0.3 mm thick plastic foil up to 0.2 m height after the bottom adjustment to the grade line. When the foil is set, the space will be filed with the material from its base up to 0.25 m height (half of the pipe trench depth), because it contains a high amount of calcium. A perforated irrigation pipe with capping strip will be placed on the new graded bottom. Then the pipe trench will be filled with the soil from its upper layer. The pipeline should not be damaged because soil will not be plowed there, only loosened up to the depth of 0.15 m. The irrigation water supplied will accumulate in the impermeable part of the pipe trench, by capillary action it will spread to about 0.2 m from the pipe trench and rise to the surface. The cross section scheme of one partial irrigation block for the subsurface laterals is shown in Figure 2.

The laterals have the same dimension and positional arrangement in the partial irrigation blocs as in the surface point irrigation. It means that each block has four laterals at the distance of 0.8 m (see Figure 1). The detailed construction of the subsurface furrow irrigation built from pipes and armatures is part of the laying pipe plan in the drawing part of the project (FILIP *et al.* 2007). Built on the pipeline near the water source – N$_1$ tank is a filter, a metal ball cock, a water meter and a manometer.

Sprinkler and furrow irrigation

The sprinkler irrigation technique is not suitable for the desert conditions, however, it has been chosen because of the agricultural reasons. It is necessary to provide sufficient soil moisture for
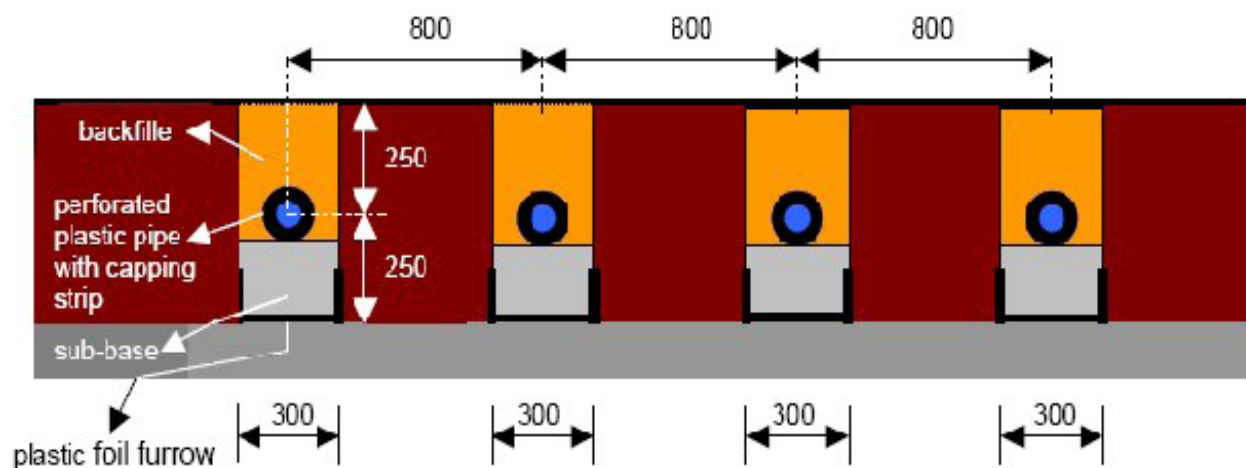
Figure 2. The cross section scheme of subsurface laterals in one of the irrigation blocks

the seed germination for most of the experimental crops in the field. Besides, classical furrow irrigation has been designed to compare the irrigation techniques used and to evaluate suitability of point irrigation, as well as to save of water used for irrigation.

Hydraulic calculation

On the basis of own approach of the point irrigation designers to the solved problem and the literary results and findings, our own method of the hydraulic calculation on PC has been developed.

The pipelines dimensions for the surface point irrigation and subsurface furrow irrigation mentioned in the previous sections have been determined by hydraulic calculation (Spitz 2007). An original hydraulic solution is presented including the evaluation of the discharge distribution uniformity from the orifices on the laterals. The most important results and references are introduced.

New computer program HYBOZAM (Hydraulika bodové závlahy pro Mongolsko/Hydraulics of point irrigation for Mongolia) showed up as the appropriate method. The program has been made and debugged in MS Excel. It consists of two subprograms (one for the lateral and the second for the supply pipelines), which concur during hydraulic dimension of the point irrigation.

The program is built on the application of three hydraulic relations: calculation of the discharge from the orifice, computation for the estimation of the pressure head loss by friction in circular

pipeline according to Colebrook-White, and calculation of the local pressure head loss in the pipeline. Part of the program is the evaluation of the discharge distribution uniformity from the orifices on laterals.

Orifice discharge

Equation:

$$q = \eta \cdot \mu \, \frac{\pi \cdot d^2}{4} \sqrt{2gH} \quad \text{(ml/s)} \tag{1}$$

where:

q – discharge from orifice (ml/s)
η – coefficient of soil resistance (–)
μ – orifice discharge coefficient (–)
d – diameter of orifice (mm)
g – gravitational acceleration 9.81 m/s^2
H – pressure head (m)

Novotný *et al.* (1989) mentions the following coefficients values of soil resistance η for subsurface irrigation:

η = 0.75 for sandy and gravelly soil
η = 0.60 for sandy loam soil
η = 0.50 for clay loam soil
For surface irrigation η = 1

Šálek (1980) recommends using orifice diameters d = 1–3 mm for point irrigation and shows the orifice discharge coefficients μ for the following orifices production technologies:

μ = 0.629 for bore orifices
μ = 0.871 for burn off orifices
μ = 0.933 for orifices with nozzle

For our calculation, the considered values are: $\mu = 0.871$, $\eta = 1$ for surface and $\eta = 0.60$ for sub-surface point irrigation.

Calculation of pressure head loss by friction in circular pressure pipeline

To determine hydraulic gradient line for energy J Darcy-Weissbach equation is used as modified by Šerek and Šálek (1973):

$$J = 8.263 \cdot 10^9 \cdot \lambda \frac{Q^2}{D^5} \quad (\%) \tag{2}$$

where:
J – hydraulic gradient line for energy (%)
λ – friction coefficient – $\lambda = f\,(Re,\, k/D)$
Re – Reynolds number = $v \times D \times \upsilon^{-1}$ (mm/m)
k – absolute pipeline roughness (mm); for plastic pipeline selected as $k = 0.01$ mm
v – central sectional water velocity (m/s)
υ – kinematic water viscosity (m²/s)
D – inner diameter of pipe (mm)
Q – water discharge in pipeline (l/s)

As apparent, Eq. (2) contains implicit friction coefficient λ, which is calculated in the program according to the equation derived by Colebrook and White; the iterative way described by Šerek and Šálek (1973) is used. λ value is calculated by the program for 16°C water temperature.

Head loss in pipeline Z is calculated as:

$$Z = \frac{J \cdot l}{100} \quad (m) \tag{3}$$

where:
J – see in Eq. (2)
l – pipeline length (m)

Determination of local head loss in circular pressure pipeline

For the determination of the local loss z arisen in the armatures and partial pipeline parts (change of the size or direction of water current velocity) in the supply pipeline and laterals for point irrigation the following equation been used:

$$z = \xi \cdot \frac{v^2}{2g} \quad (m) \tag{4}$$

where:
ξ – coefficient of local loss (–)
v – central sectional velocity (m/s)
g – gravitational acceleration 9.81 m/s²

The values of the coefficient of local loss ξ were presented by e.g. Šerek and Šálek (1973), Kolář et *al.* (1983), Tesařík *et al.* (1983, 1985) and also Spitz (2007).

Statistical evaluation of discharge distribution uniformity from orifices on laterals

For the evaluation of the discharge distribution uniformity from the perforated laterals, it is possible to use different methods as briefly presented by Zdražil and Spitz (1966). Czech standard TNV 75 4310 (1998) recommends to use C_u uniformity coefficient according to Christiansen, eventually K coefficient of non-uniformity. Despite this both coefficients were calculated on the laterals, the predominant criterion for the evaluation having been the calculation of K_{ef} coefficient of uniformity according to the following equation:

$$K_{ef} = 100\frac{p_{ef}}{o}\,(\%) \tag{5}$$

where:
p_{ef} – number of orifices with discharge, which show the deviation $\pm \Delta\%$ from the mean discharge value q_p
o – total number of active orifices on a pipeline

The calculation of K_{ef} according to Eq. (5) is a modified evaluative method recommended by the above cited authors. Δ deviation related to Eq. (5) is selected, it is recommended to put $\Delta = \pm 10\%$. The detected K_{ef} value is in comparison to previous evaluating coefficients C_u and K sufficiently transparent, which is the reason why it was chosen as the main one for the evaluation of the discharge distribution uniformity from perforated laterals.

Brief description of HYBOZAM program

As already mentioned, HYBOZAM program consists of two subprograms, which concur during hydraulic dimensioning of point irrigation. A subprogram exists for the lateral and another one for the supply pipelines.

Subprogram for the lateral. The subprogram for the laterals is made in MS Excel for maximum number of orifices $n = 161$ on a lateral. The capacity corresponds to the requirements for hydraulic calculation of point irrigation for a particular block in Mongolia. The surface and subsurface irrigation calculations have been done in the calculating sheet "Zx lateral", where x equals the number of particu-

lar laterals. The subprogram component has also graphical expression of calculation in sheets called "Graph of Zx lateral". In the case of the need to open out the program for more orifices, this is possible and simple.

The calculation is done from the end of the lateral to the beginning, which means from the last orifice of the lateral to the first one.

Subprogram for supply pipeline. The subprogram for the supply irrigation point pipeline is made in MS Excel for maximum irrigation pipeline nodes *n* = 30. The calculations have been done in the calculating sheet "R1 supply pipeline". The input data for the subprogram result from the calculation sheets "Zx lateral" of the subprogram for the lateral.

The calculation is done from the end of the supply pipeline to the beginning, that is from the last sector of the pipeline to the first one, the same as with the lateral.

Hydraulic calculation procedure. Hydraulic calculation has been done for the most unfavourable case of the surface and subsurface point irrigation, which is the partial irrigation block the most distant from the water source. The calculation process was as follows:

At the beginning, the inside diameters of laterals Z1 a Z2 (see Figure 1) and hydraulic evaluation were applied so that the calculation starts from the

end of the laterals. Firstly (in all variants 1), for the surface and subsurface irrigation one pipe diameter was set. The observed discharge uniformity from the orifices evaluated by equation (5), which is K_{ef} coefficient, was inconvenient. Uniformity improvement is possible by many different ways: e.g. by the change of the orifices diameter size, by the change of the orifices spacing, and by the combinations of two and more pipe diameters at the lateral. The last way, which is the simplest to make and almost eliminates a wrong irrigation placing was used to improve the discharge uniformity. As mentioned, a combination of two plastic pipelines was designed with the pipe diameters of 35.4 /40 mm and of 28.2/32 mm and the length of 20 m for the laterals (in all variants 2).

The main result is the pressure head input, irrigation discharge and the value of K_{ef} coefficient of the discharge distribution uniformity from the perforated lateral with the deviation $\Delta = \pm 10\%$ from the mean discharge q_p. For the visual evaluation of the uniformity, graphs of laterals Z1 and Z2 were constructed. Also were presented the values of discharge and pressure head in each orifice for both laterals Z1and Z2. An example is shown in Figure 3.

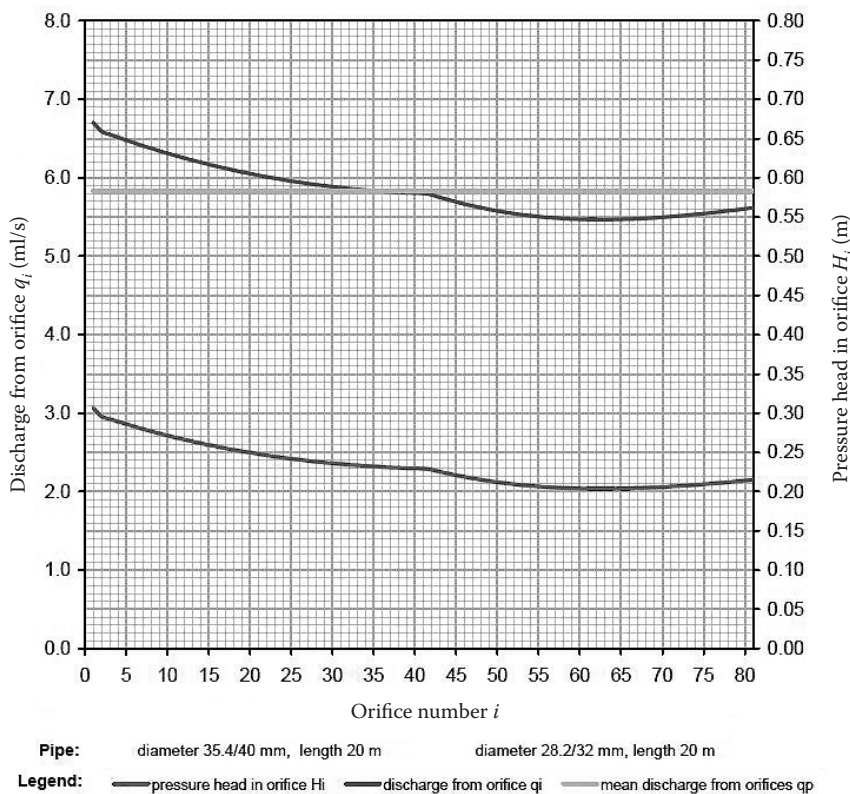The observed pressure head inputs and discharge inputs to Z1 and Z2 according to the program are

Figure 3. Discharge from orifice q_i, pressure head in orifice H_i and mean discharge q_p from orifices on lateral Z1 for surface point irrigation – variant 2.

Table 1. The most important calculated results for surface irrigation – variant 2

Supply pipeline		Lateral							
R1		Z1				Z2			
Q	H	Q_1	H_1	H_{81}	K_{ef}	Q_1	H_1	H_{81}	K_{ef}
(l/s)	(m)	(l/s)	(m)		(%)	(l/s)	(m)		(%)
1.871	2.957	0.465	0.306	0.215	92.59	0.470	0.322	0.220	92.59

Q, Q_1 – input discharge; H, H_1 – imput pressure head; H_{81} – pressure head at terminal nod; K_{ef} – coefficient of uniformity with deviation $\Delta = \pm 10$ (% from q_p)

automatically transferred to hydraulic equation for the supply pipeline of point irrigation R1. Inside diameters were designed, in particular, of the supply piping pieces, and the irrigation point thus completed was evaluated hydraulically; it started again from the outermost end of the pipeline. In the nodes of the parallel joints, for each lateral on the submain pipeline equal value of the pressure head at the lateral and of the pressure head at the submain pipeline must be determined. If it is not the case, the pressure head at the end of the laterals is adjusted till both values are equal. Because the laterals location, considering the connection onto the submain pipeline, is symmetric, then in its sectors, which discharge into both symmetric parts, a double discharge set has been detected in each part.

By a gradual design of the inside diameters in sections of the supply pipeline R1 and the terminal pressure head heights of laterals Z1 and Z2, the Q pipeline discharge lower than or equal to 2 l/s has been reached and at the pressure head H has been lower or equal to 3 m at the beginning of the supply pipeline. At the same time it was important to pay attention to the discharge distribution uniformity from the orifices on the laterals evaluated by the coefficient of uniformity K_{ef}, which should be suitable. An example of the most important results calculated for surface irrigation – variant 2 is presented in Table 1. It is clear, that hydraulic requirement and, required uniformity of water discharge from the orifices on the laterals have been fulfilled.

Operational data

Regarding the calculated operational data, it is possible to mention the most important ones as: irrigation depth 25 mm is sufficient to irrigate an experimental field of 128 m^2 (partial irrigation block) in 0.45 h, the whole area 2432 m^2 in 8.45 h. It means that cca 0.45 h stepwise irrigation of experimental fields allows the irrigation of the whole area of 2432 m^2 in one day.

CONCLUSION

HYBOZAM program, which designs a pipeline dimension of the point irrigation in Mongolia and its evaluation, has been proven as a suitable tool for the intended use. The program runs quickly and reliably and gives the user foolproof results. The calculation outcomes mainly depend on the input data used.

Some input data have been taken from the literature; some have not been evaluated because of objective reasons. These are above all the values of the orifice discharge coefficient μ, which was taken from the available literature as well as the coefficients of local loss in the pipeline ξ. It is important to see them as approximated. Also the data from Mongolia are not all reliable. For example, the slope of the irrigated area, which was estimated as flat land, as well as the location and water yield of the possible drill hole, which were not available during the time of the irrigation designing. However, the program will offer more precise calculation after the data are refined.

Coefficients μ and ξ have not been experimentally proven due to the lack of time. Also the plastic pipeline, which was bought in China, did not fully meet the calculated dimensions. The alignment works for the point irrigation were done only with primitive tools, because the container containing geodetic tools, which had been sent from the Czech Republic, was stopped at the border with Ukraine and arrived to Mongolia with almost 2 months delay. Its late arrival influenced also the agronomical equipment for the experimental fields in Mongolia.

Despite all the problems mentioned, the point irrigation was built and operated satisfyingly. According to experts, the irrigation was functioning well, which could be seen at the yields of the following crops: cucumbers, carrots, radish, potatoes, etc. For example, the surface point irrigation was used for potatoes, where the experts recorded the tuber yield of 1.76 kg/m^2 while the irrigation water consump-

tion was 298 l/kg of harvested tubers per vegetation. The furrow irrigation showed the tuber yield of 1.58 kg/m^2 while the irrigation water consumption was 490 l/kg of harvested tubers per vegetation. Due to the demanding work of the experts from the Mendel University in Brno, no more quantitatively and qualitatively evaluated operational parameters of the point irrigation could be obtained.

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