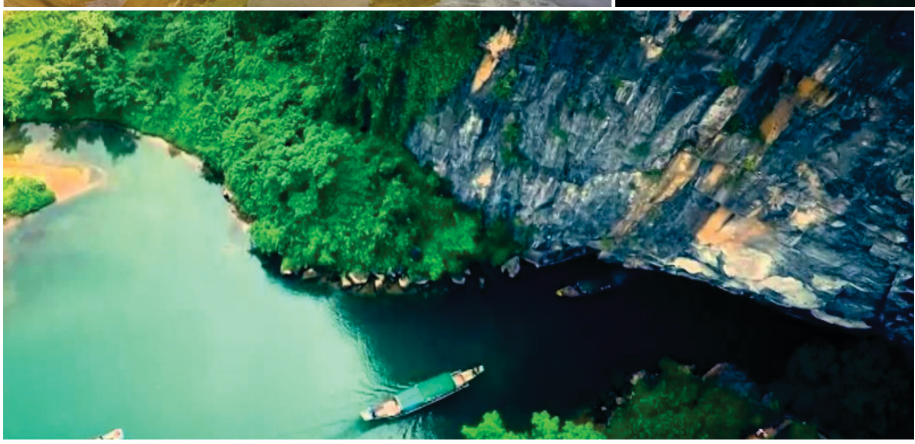
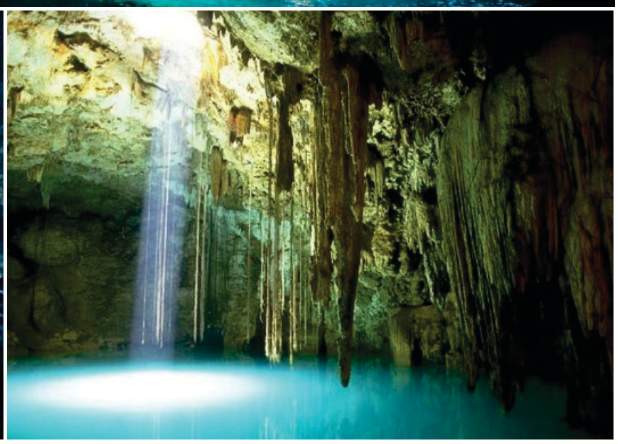
PROCEEDINGS OF THE 4th INTERNATIONAL CONFERENCE VIETGEO 2018, QUANG BINH, 21-22 SEPTEMBER, 2018

GEOLOGICAL AND GEOTECHNICAL ENGINEERING IN RESPONSE TO CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT OF INFRASTRUCTURE



SCIENCE AND TECHNICS PUBLISHING HOUSE

TABLE OF CONTENT

SESSION 2
GEOTECHNICS FOR SUSTAINABLE DEVELOPMENT OF INFRASTRUCTURE

SESSION 3
GEOTECHNICAL MONITORING AND MATERIALS

SESSION 4
GEOHAZARDS AND SLOPE STABILITY

SESSION 5
TECHNICAL NOTES

PHYSICAL SCALE MODEL OF HORIZONTAL WATER COLLECTING SYSTEM FOR WEIRS IN THE NORTHWEST VIETNAM

Nguyen Huy Vuong[1], Nguyen Chi Thanh[1], Pham Tuan[1], Tran Van Quang[1], Vu Le Minh[1], Vu Ba Thao[1], Bui Truong Son[2]

[1]Hydraulic Construction Institute, Vietnam

[2]Hanoi University of Mining and Geology, Vietnam

Corresponding author' Email: huyvuongdkt@gmail.com

Abstract: In Northwest region of Vietnam, there are 11,276 weirs which are working on provide industrial water and 9,718 ones to provide drinking water. However, degradation has occurred seriously to those constructions. There are plenty causes of those degradation, but the common one is deposition happening in upstream and in front of water intake. This paper presents results of physical scale model experiment which contributes to research on a horizontal water collecting system on river (stream) bed (HWCS) replace traditional methods. It indicates correlation between particle size distribution (PSD), coefficient of permeability, gradient of permeability, tightness, hydraulic gradient with capability of collecting water of different filter pipes. The results also prove that among those boundary conditions, the tube with wireframe structure reaches the highest efficiency. For this type of tube (slit rate of 27.3%), the amount of water obtained can reach 0.4 to 6.0 liter/s/m, depending on PSD.

Keywords: weir; deposition; water intake; water collector on river bed; Northwest Vietnam.

1. Motivation

A common solution to exploit groundwater is vertical exploitation, e.g. wells and well corridors. Presently, thanks to technology development, together with increasing in water demand and to reduce effects on aquifer; several horizontal systems have been applying to withdraw groundwater in regions where there are thin aquifer, shallow groundwater level. Advantages of this method was analyzed by Hunt et al. (2002) [1] .The horizontal system can collect a high amount of water, especially when it is applied on river bed, and nowadays it becomes more and more popular. In the U.S, a number of HWCS have been constructed in Kentucky [2] and California [3]. In South Korea, there are 10 HWCSs functioning, and 20 other ones are in construction. In 2003, Chen and Zhan presented a physical model to study the change of permeability gradient along filter pipe [4]. Zhan and Zlotnik did a research on decrease of water level that occurs around a limited horizontal filter pipe in unconfined aquifer [5]; and in 1962, Hantush and Papadopulos firstly announced results of analysis of flow velocity through a horizontal collecting pipe on river bed [6]. A research on groundwater movement (including flow rate and velocity) to a horizontal filter pipe (diameter of 30.0*mm* and 2.6*m* long) was presented by Kim et al. in 2012 [7]. The effects of geology condition to a horizontal filter pipe and a collecting well were publicized by Mohamed and Rushton in 2006 [8]. In Europe, design and construction of water collecting system on river bed mainly depends on working of Grischek et al. (2002) [9]. Over a long period, most of the publications have not indicated correlations between hydrogeological characteristics (i.e. grain composition, coefficient of permeability, permeability gradient, tightness…) and filter pipe features (openness, slit/diameter ratio, slope), especially they did not consider influence of surface runoff on working of HWCS.

In Northwest Vietnam, the precipitation rate is low, 1500*mm* approximately, while evapotranspiration can reach 800*mm* annually. Its terrain is very craggy and strong cleavage; high mountains intersperse by narrow valleys. This leads to small irrigation area, scattered distribution and the main solution for water demand is weirs. This type of construction is a barrier across the horizontal width of a river or stream and results in river level rise, creates water head for gravity irrigation. Presently, in the region, there are approximately 11,276 weirs working for production demand and 9,718 weirs for drinking water. Due to effects of terrain, geology and hydrology conditions, weirs are strongly vulnerable to disasters, especially muddy-rocks flood and landslides. After a rainy season, most of the weirs in the region are completely filled up by deposition upstream and result in block of water collecting systems.

Fig. 1. Deposition blocks upstream and paralyze water collecting system of weirs in the Northwest

Deposited materials are mainly gravel with sand which has a high coefficient of permeability, high water circulation rate; however due to high stream slope, depth of the deposition layer is usually thin, varies in range of 2.0 ÷ 3.0m. In order to utilize this characteristic and guarantee functioning of weirs through extreme conditions, we purpose a new method that can overcome all the disadvantages of traditional water collecting systems. An unscaled schematic of the method is illustrated in Fig. 3.

Base on experiment of physical scale model with different PSDs, different types of filter pipe and different hydraulic conditions, this paper analyzes correlations among those factors and then selects an optimal structure to design a HWCS.

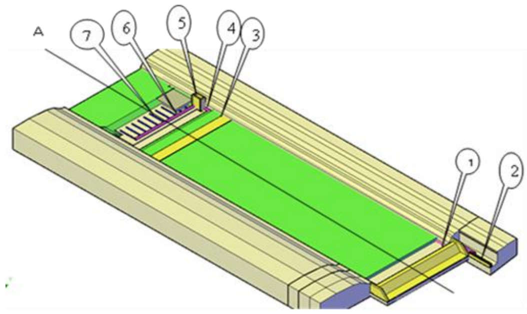


Fig. 2. Schematic of the proposed method

1. The current weir
2. Water collecting canal
3. Underground dam
4. Pipe that directs water to the old canal
5. Water tank
6. Pipe that collects water from filter pipe system
7. Filter pipe

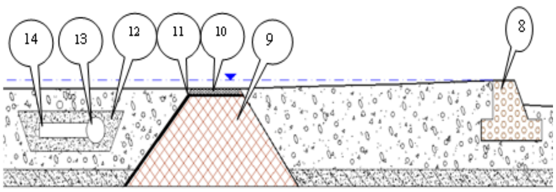


Fig. 3. Cross-section of the proposed method

1. The current weir;	5.Filter layer (standard sand);
2. Underground dam;	6. Water collecting pipe;
3. Protecting layer;	7.Filter pipe.
4. Waterproof fabric HDPE;	

2. Physical model experiment

The physical scale model aims to simulate functioning of water collecting system on river/stream bed, purposes to replace traditional method of weirs in the Northwest region. The model reproduced geohydrology condition of alluvial structure of stream bed in the region; with main characteristics: dimensions, alluvial materials, permeability gradient and water collecting process of several typical types of filter pipe. The model has dimensions of 2.0x2.0x1.5*m* (not including its ase); its surrounding and bottom are covered by tempered glass (12.0*mm* thick) (Fig. 4)

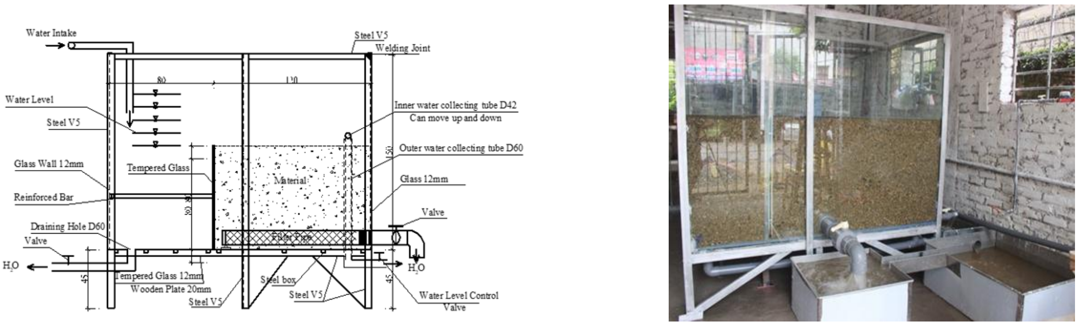


Fig. 4. Physical scale model and its cross-section

2.1. Experiment materials

The chosen materials permeability characteristic of alluvial material in the Northwest region. PSD is one of the factors that can affect permeability characteristic, in which the particle group that has major effect on permeability of the entire distribution is D_{10} (D_{10} is the diameter at which 10% of the sample's mass is comprised of particles with a diameter less than this value) [10]. The alluvial materials in the area mainly consist of big gravel mixed with pebbles and sand; pebble mixes with sand; and combination of rock and soil. In which, D_{10} group is commonly sand (from small grain 0.1÷0.25*mm* to moderate grain 0.25÷0.5*mm*) and small pebble (2.0÷5.0*mm*). In this paper, we consider three typical type of PSD as in Fig. 5.

a b c

Fig. 5. Types of material used for the physical model

a. Pebble b. Pebble mixes with sand c. Sand (moderate grain size) mixes with pebbles

Tab. 1. Physical characteristics of experiment material

Material	PSD (%)				Particle grain size at P=10% (mm)	Porosity max	Porosity min	Permeability coefficient Dr = 0,35 (x 10^{-2})	Permeability coefficient Dr = 0,65 (x 10^{-2})
	gravel	pebble	sand	silt					
a	4.1	90.2	5.5	0.2	2.314	0.677	0.513	50.4	29.14
b	0.0	55.0	41.9	3.1	0.284	0.647	0.417	8.84	3.57
c	1.8	39.4	55.8	3.0	0.228	0.703	0.427	6.63	2.26

Experiments were taken to determine physical characteristics of those materials. The permeability coefficient of each type was done with 02 relative tightness: Dr = 0.35 and Dr = 0.65 (Table 1).

2.2. Permeability gradient

The depth of pebble-gravel layer of stream is in range of 2.0*m* and 3.0*m*. In this alluvial layer, water is provided directly by surface runoff. Permeability gradient is reproduced as in Table 2.

Tab. 2. Reproduction of permeability gradient

Water head (cm)	Thickness (cm)	Permeability gradient
110	68	1.62
100	68	1.47
90	68	1.32
80	68	1.18
70	68	1.03

2.3. Filter pipes

To apply research results to reality, it requires appropriate cost as well as suitability of geohydrology conditions of the stream's alluvial layer. The pipes were chosen as in Figure 6 and their characteristics are shown in Table 3.

Fig. 6. Types of filter pipe used in experiment
1. K-CD d110; 2. K-CD d68; 3. OL d124; 4. OL d105; 5. XK d90

To identify the optimal slope of filter pipe, we did experiments with hydraulic gradient i = 0%, 1.5% and 3%.

Tab. 2. Filter pipes' characteristics

Type of filter pipe	Pipe characteristics	Outer diameter (mm)	Slit area (cm^2)	Slit rate (%)
Wire-winding pipe D110 (K-CD d110)	Frame structure, covered by wire winding around, gap between wires is 1.0*mm*.	110	942	27.3
Wire-winding pipe D68 (K-CD d68)	Frame structure, covered by wire winding around, gap between wires is 0.5*mm*.	68	345	19.6
Mesh pipe D124 (OL d124)	Steel, D=110, holes D=10.0*mm* on pipe body, covered by mesh (size 0.5*mm*)	124	578	16.7
Mesh pipe D105 (OL d105)	Plastic PVC D=90, holes D=10.0*mm* on pipe body, covered by mesh (size 1.0*mm*)	105	345	12.2
Slit pipe D90 (XK d90)	Plastic PVC, slits are cut on pipe body, slit width is 0.*3mm*	90	226	8.0

3. Experiment scenarios

All the scenarios are illustrated as in Fig. 7.

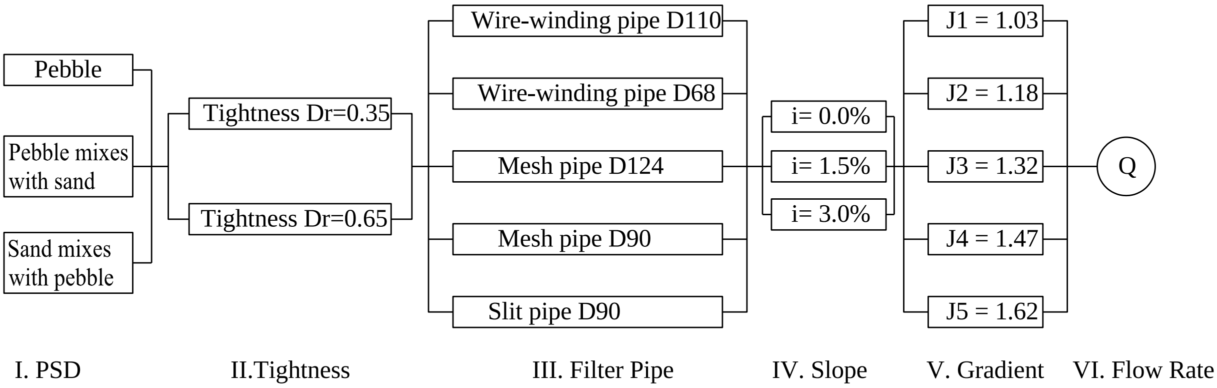


Fig. 7. Experiment scenarios

4. Results

4.1. Correlation between permeability environment and capability of collecting water for different types of filter pipes.

The permeability environment plays an important role to select and determine an optimal solution for water collecting system. In order to determine more comprehensively the effects of permeability environment, we considered two main factors, i.e. PSD and permeability coefficient.

PSD is one of the major factors that decide permeability coefficient of experiment materials, thus it also has effects on flow rate collected by filter pipes. The previous researches had indicated correlation between PSD's characteristics; i.e. D_{10}, the uniformity coefficient Cu = D_{60}/D_{10} (D_{60} is value that 60 % of the soil particles are finer than this size), the coefficient of curvature Cc; and coefficient of permeability of the environment[1]. The diameter D_{10}, uniformity coefficient Cu is directly proportional to the environment's permeability coefficient. However, there is no research on effects of PSD on functioning process of filter pipe, hence the selection of PSD still has difficulties. This research has indicated the correlation between PSD and collecting water capability (Fig. a).

Permeability coefficient of environment is the key factor to design the filter pipe system due to its effects on capability of collecting water. Even though, this correlation has only be considered to design vertical collecting systems; hence in this paper, we established the correlation of permeability coefficient of environment and collecting water ability of several typical filter pipes to design water collecting system (Fig.)

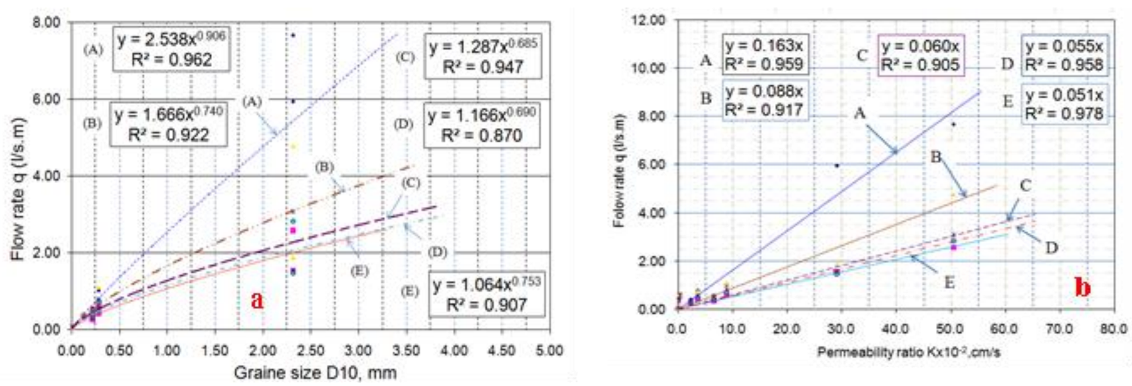


Fig. 8. Influence of PSD on capability of collecting water of filter pipes.

(a) D10 vs flow rate (b) Permeability coefficient vs flow rate

A: K-CD d110; B: OL d124; C: XKd90; D: OL d105; E: K-CD d68

4.2. Correlation between permeability coefficient of environment and type of filter pipe.

Classification of filter pipe is characterized by their diameters (D), slit area (Sr) and shapes. As mentioned above, in order to design a horizontal water collecting system, the interaction between types of filter pipes and environment's permeability requires more investigation. This paper established correlation between environment's permeability and flow rate/ pipe's diameter ratio (q/D) and flow rate/ slit area ratio (q/Sr) (Fig.).

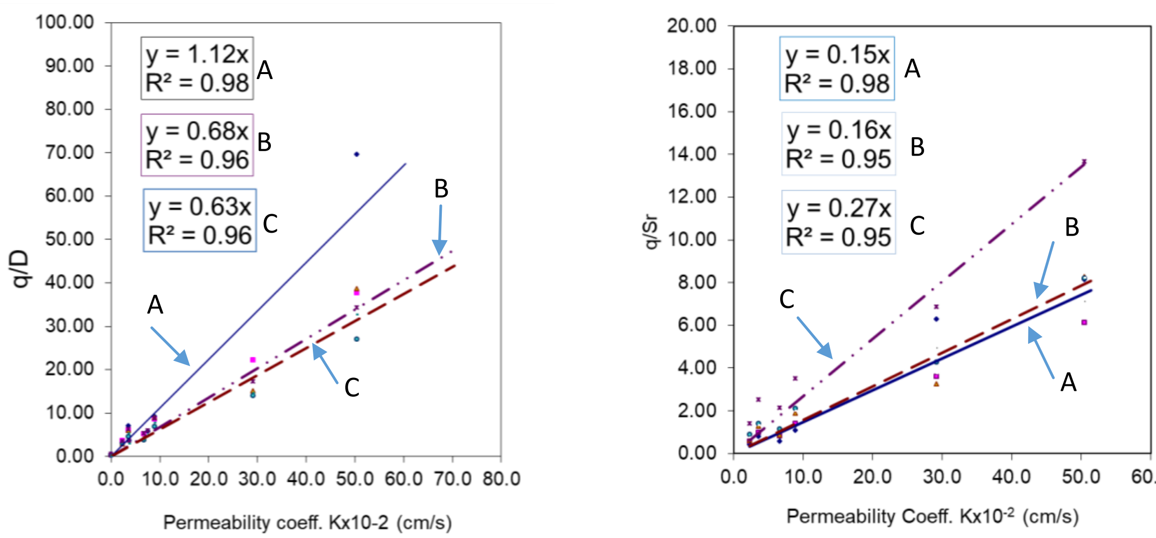


Fig. 9. Correlations between types of filter pipes and environment's permeability
A: Wire-winding Pipe B: Slit pipe C: Mesh Pipe

The experiments proved that change of flow rate against particle size distribution is the most stable in case of wire-winding pipe; then slit and mesh pipe stands behind respectively. Over the operating process, wire-winding pipe also was least affected by blocking of particle (Fig.).

(a) (b)

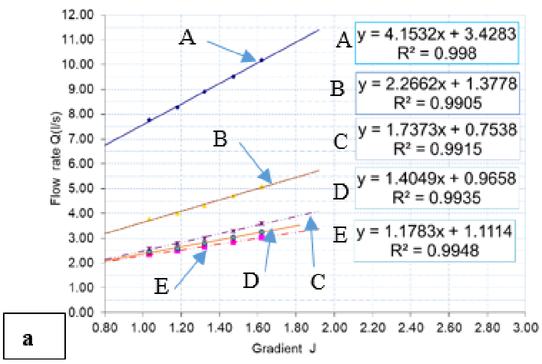
Fig. 10. The wire-winding pipe (a) and slit pipe (b) after experiments.

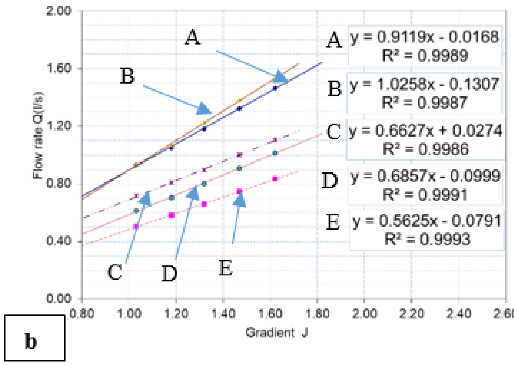
4.3. Effects of permeability gradient on filter pipe's capability of collecting water.

Permeability gradient has directly effect on environment permeability and operation of water collecting system. Darcy and Bernoulli had done number of researches on correlation of permeability coefficient and permeability gradient.

In order to select the optimal depth to install the filter pipe system.

As can be seen in Figure 11, the increase of permeability gradient results in the increase of flow rate of water collected by filter pipes, however this increase is not stable among the filter pipe types due to their characteristics, PSD and tightness of materials as mentioned above.





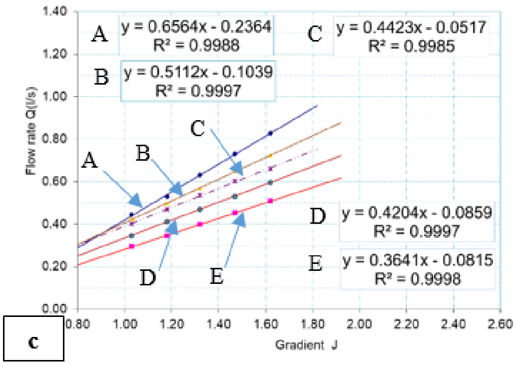


Fig. 11. Correlation between ground materials and capability of collecting water of filter pipes (a) Pebble (b) Pebble mixes with sand (c) Sand (moderate grain size) mixes with pebbles
A: K-CD d110; B: OL d124; C: XKd90; D: OL d105; E: K-CD d68

4.4. Correlation between material tightness and filter pipe's capability of collecting water

The material will be tighter over a specific period working under water. In this paper, the tightness Dr = 0.35 represents the case when the construction just completed, Dr = 0.65 is for the case after a period of operation when PSD tends to be tighter due to pressure of seepage and water head. In reality, after a long time of experiments with water level was rose up and down, the original tightness has changed depending on types of materials; from Dr = 0.35 to 0.55, 0.47, 0.4 in case of pebbles (a), pebble mixes with sand (b) and sand (moderate grain size) mixes with pebbles (c), respectively (the materials can be seen in (Fig. 5)).

The compacted ratio is characterized by decrease of porosity n (%) which can be recognized by parameter Dr/D102. As can be seen in *Fig.* , flow rate decreases when the ratio Dr/D102 increases. When the material is compacted well, the effective porosity will decrease and lead to decrease of flow rate, however flow rate is more stable for smaller particle sizes in all experiments of filter pipes. The tightness keeps small particle, prevents underground erosion; hence the permeability becomes more stable and reduces blocking of narrow-slit pipes.

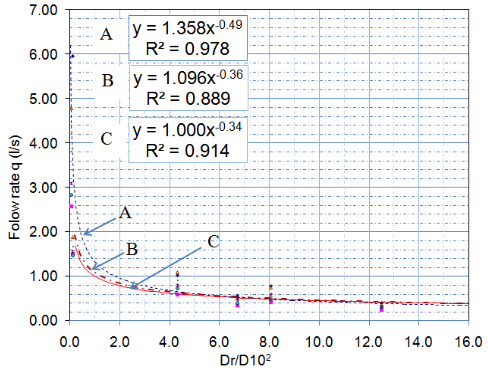
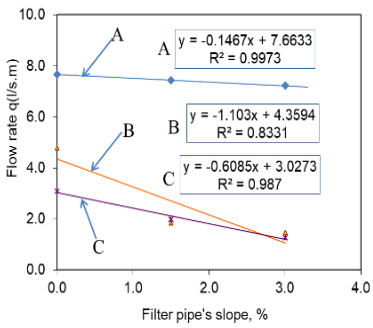


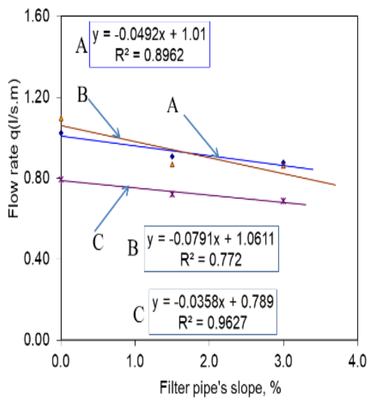
Fig. 12. Filter pipe's capability of collecting water and material's tightness A: wire-winding pipe; B: Mesh pipe; C: Slit pipe

4.5. Effects of the hydraulic slope on filter pipe's capability of collecting water.

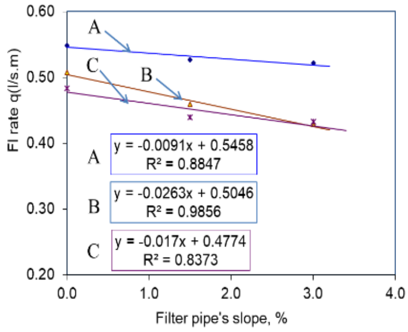
The slope of filter pipe has effects on capability of collecting water and its long-term operation of the entire water collecting system; and we set up three slopes 0%, 1.5% and 3% for each type of materials of pebbles (a), pebble mixes with sand (b) and sand (moderate grain size) mixes with pebbles (c). The results are presented in Fig. 136.



(a)



(b)



(c)

Fig. 136. Flow rate vs filter pipe slope in different environment (a), (b), (c)
A: wire-winding pipe; B: Mesh pipe; C: Slit pipe

In case of pebbles (a), the filter pipe slope does not show much effect on flow rate of wire-winding pipe, but decrease considerably flow rate of other pipes. The material (b) and (c) shows a lower rate of flow decrease. Base on those analysis, it is proved that the smaller particle size and the lower permeability coefficient, the lower effect of pipe slope on collecting water. For the filter pipe with big area and slit (i.e. wire-winding pipe D110), the flow rate show an inconsiderable decrease when the pipe slope increases; and for the material (a), the flow rate at slope 3% is higher than it is at slope 1.5%.

The filter pipe slope should increase permeability, but in this case it reduces flow rate. When the filter pipe inclines, the vertical component of slit area reduces and leads to decrease of flow rate and easily block. In addition, the pipe's bottom becomes easy to contain air when the pipe is full of water; and consequently there is a decrease of flow rate. In order to prevent air in the pipe, it is necessary to set up a vent pipe in the pipe bottom's cover. The vent pipe functions more effective for mesh and slit pipe; and air can strongly escape when the valve is locked.

5. Conclusion

The physical scale mode reproduced properly the water collecting system on river/stream bed and its operation in reality. The experiments carried out correlations between PSD, permeability coefficient, gradient, tightness, hydraulic slope and the filter pipe's capability of collecting water for different types of filter pipes.

The correlation between permeability coefficient and collecting water ability was the most reliable, thus it was chosen to select filter pipe's characteristics. The usage of filter pipe with big slit, i.e. wire-winding pipe, can get high flow rate; however if it does not require high discharge, mesh pipe and slit pipe can be applied. Dimensions of slit, mesh of filter pipe should be higher than 1.0mm. The pipe's slope can reduce flow rate collected by filter pipe, especially when slit width is larger than 1.0mm; however it should bear in mind that the filter pipe should incline toward the collecting pipe by slope 1.5% to avoid deposition. The tightness of PSD is able to reduce but stabilize flow rate of filter pipes. To design a HWCS, we recommend to use experiment results and PSD with relative tightness Dr = 0.65

Acknowledgements

This research is a part of the National project "Research and Propose to Apply the Appropriate Scientific and Technological Solutions on Improving Efficiency of Weirs in the Northwest Vietnam, Code name: KHCN-TB.14C/13-18, implemented by Vietnam Academy for Water Resources.

We thank the Vietnam National University, Hanoi and the Program of Science and Technology to Sustainable Development of the Northwest region KHCN-TB/13-18 to fund the project KHCN-TB.14C/13-18 and this research.

References

[1] H. Hunt, J. Schubert, and C. Ray, "Conceptual design of riverbank filtration systems," in *Riverbank Filtration*, Springer, 2002, pp. 19–27.

[2] J. Wang, "Riverbank filtration case study at Louisville, Kentucky," in *Riverbank Filtration*, Springer, 2002, pp. 117–145.

[3] J. Jasperse, "Planning, design and operations of collector 6, Sonoma County Water Agency," in *Riverbank Filtration for Water Security in Desert Countries*, Springer, 2011, pp. 169–202.

[4] C. Chen, J. Wan, and H. Zhan, "Theoretical and experimental studies of coupled seepage-pipe flow to a horizontal well," *J. Hydrol.*, vol. 281, no. 1–2, pp. 159–171, 2003.

[5] H. Zhan and V. A. Zlotnik, "Groundwater flow to a horizontal or slanted well in an unconfined aquifer," *Water Resour. Res.*, vol. 38, no. 7, pp. 11–13, 2002.

[6] M. S. Hantush and I. S. Papadopulos, "Flow of ground water to collector wells," *J. Hydraul. Div.*, vol. 88, no. 5, pp. 221–244, 1962.

[7] S.-H. Kim, K.-H. Ahn, S. O. Prasher, and R. M. Patel, "Extending riverbed filtration design velocity for horizontal wells from model to prototypes.," *Can. Biosyst. Eng.*, vol. 54, 2012.

[8] A. Mohamed and K. Rushton, "Horizontal wells in shallow aquifers: Field experiment and numerical model," *J. Hydrol.*, vol. 329, no. 1–2, pp. 98–109, 2006.

[9] T. Grischek, D. Schoenheinz, and C. Ray, "Siting and design issues for riverbank filtration schemes," in *Riverbank Filtration*, Springer, 2002, pp. 291–302.

[10] E. M. Onur, "Predicting the permeability of sandy soils from grain size distributions." Kent State University, 2014.