PRESSURE VARIATION IMPACT ON DISCHARGE CHARACTERISTICS OF POROUS PIPES

A. Janani[1], T. Sohrabi[2], H. Dehghanisanij[3]

ABSTRACT

Porous pipe is a lateral pipe introduced for subsurface micro irrigation. A laboratory study was conducted to investigate the effect of operating pressure on the discharge characteristics of porous pipe. Three-meter of porous permeable.
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characteristics of porous pipe micro irrigation. The equation of emission rates and the pressure, emission variation along the pipe, emission variation of pipe by time, coefficient of variation, and emission variation were tested in different pressures of 3.5, 7, 10.5, 14, 17.5, and 21 meter. Experimental results showed that emission rate decreased by time and after 5 hours, the emission rate at different pressures is approximately declined 10 to 20 percent. The relationship between pressure and discharge rate was linear with high correlation coefficient.

Keywords: porous pipe, micro irrigation, discharge characteristics

1. INTRODUCTION

A porous pipe, extruded from recycled automobile tire rubber and polyethylene granules, has been used in microirrigation which is regarded as one of the most efficient irrigation methods for relief of water supply shortage in dry regions. But potential clogging and non-uniform emission has impeded the widespread applications of the porous pipe. (Alam, 1991)
Experimental studies of porous pipe discharge characteristics have been reported recently (Haijun et al.,2009). Both laboratory and field test results indicated that the emission rates of porous pipes declined initially and gradually arrived at a stable emission rate. It is now clear that the manufacturing technology determines the porosity of the pipes. However, the discharge characteristics depend on not only the porosity but the operating conditions as well. Among all the affecting factors, operating pressure is the most important. Some reports (Kang, 2000 and Povoa and Hills 1994) on microirrigation showed that the water application uniformity and emitter plugging varied with operating pressures. As the rubber-based porous pipes are flexible and elastic, the porosity and permeability vary in response to operating pressure resulting in the changes of emission pattern. Moreover, in field application practice regulating hydraulic pressure is an essential means for microirrigation to

1- Graduate Student, University of Tehran, Karaj Iran
2- Professor, Faculty of Water Science Engineering, University of Tehran, Karaj Iran
3- Assistant Researcher, Agricultural Engineering Research Institute, Karaj, Iran.
P.O.Box: 31585-845. dehghanisanij@yahoo.com

achieve the desired irrigation purpose. Hence, it is necessary to investigate the effect of hydraulic pressure on the emission performance of porous pipes before any microirrigation application design. However, there are few published reports on this aspect, and little is known about it. This research aims at, under laboratory conditions, the effects of operating pressure on emission rate and emission uniformity. The objective of the research work is to provide some suggestions for the application design of the microirrigation lateral.

Similar products have been used in the US as subsurface micro irrigation laterals in orchards (Alam, 1991) and in turf grasses (Rauschkolb et al., 1990). It is also believed that the porous pipe can also be useful for simple microirrigation systems such as those described by Batchelor et al. (1996). In Australia, the porous pipe is currently being marketed as `Leaky Pipe' and `Aquapore,' for subsurface irrigation of turf and landscape. Unlike conventional micro irrigation (drip) laterals which have discrete emitters at specified distances, the porous pipe emits water throughout its entire length as water is passed through it under pressure. Since the porous pipe is both conveying and emitting water, the relationship between flow and discharge is critical. Various field and laboratory studies, such as those of Lomax et al. (1986), Melano and Kamaladasa (1993) and Smajstrla (1992, 1994) have dealt with this aspect. The major finding was that emission rates of the products declined continuously with time, most probably due to a reduction in the permeability of the lateral with time. Melano and Kamaladasa (1993) described the flow rate decline and establishment of stable discharge as a curing process and reported from bench testing that curing was best achieved with an operating pressure of 25 kPa. In long-term field studies, Smajstrla (1992) demonstrated that flow rate decline of buried porous pipe was better controlled with the use of flow control valves rather than by regulating pressure. Later, Smajstrla (1994) confirmed that stable flow rates could be achieved only with flow control valves operated at pressures of 380±415 kPa. Another aspect of the porous pipe that has not been adequately reported is the uniformity of water application of the product with respect to its length. Since the porous pipe emits water continuously along its length when used as a micro irrigation lateral, its porosity with respect to its length must be uniform to ensure uniformity in the water application. Yoder and Mote (1995) reported on some of the quality control problems facing manufacturers of porous pipe. Although the temperature at the extruder and the rate of extrusion are adjusted to provide the desired product, the size and distribution of the pores in the pipe are not directly controlled and a finished product with considerable discharge variation, both within and between manufacturing lots, is produced.

Therefore when a particular type of porous pipe is used as a micro irrigation lateral, several questions become important. How much discharge variation exists within a given lateral length? Where does the variation occur? How stable is the discharge with time? This paper aims at providing some answers to the above questions, together with other operating characteristics of a commercial rubber-based porous pipe (`Leaky Pipe'). The objectives of the research were to study in the laboratory the effects of applied pressures and filtration on the emission rate of the product and to assess the uniformity of water application under different operating conditions.

2. MATERIALS AND METHODS

The experiments were carried out in the hydraulic laboratory of Irrigation Technology Department in Agricultural Engineering Research Institute. All the tests were carried out at room temperature (20-25℃) on a set of special apparatus. For all tests, 3 pieces of Porous pipe with 3 m long and 16 mm internal diameter were cut as replication from a 100 meters roll. Their surfaces were black and coarse. Porous pipe was set horizontally on a specific water collector.

Unlike conventional microirrigation laterals such as drip tapes that have discrete emitters at specific distance, porous pipes emit water throughout their entire length as water penetrates under certain pressure. For the purpose of examining the emission uniformity, in this study, a PVC pipe 3 meters long and 200 mm in diameter to collect water leaking from porous pipe was used as shown in Fig. 1. The PVC pipe was divided equally into 30 portions, and each of them gathered the flow from the porous pipe, so that the flow rates of 30 segments of a porous pipe were measured simultaneously in each test. Two manometers were connected with the pipe at the head and end to gauge the internal hydraulic pressure. Uniformity of water application of drip systems is normally assessed by determining the coefficient of variation (CV) of the system from flow measurements from individual emitters (Solomon, 1976). For the porous pipe, however, because of continuous emission of water along the length, the test bench was modified to measure flow from 0.1 m portions of the pipe and to calculate the CVs from the data obtained. For this purpose, a PVC trough, 3 m long and 200 mm diameter was partitioned into 30 hermetically sealed portions (see Fig. 1). In order to find out the emission variation along the pipe, each 0.1 m segment of the porous pipe, corresponding to a compartment of the trough, was considered as an emitter (Fig.1), from which the volume of water emitted for every 20 minutes was measured one by one in all tests. It reviews the pressures (3.5, 7, 10.5, 14, 17.5 and 21 m) for 5 hours for each pressure was done. From experimental results two important discharge evaluation parameters, pipe emission rate (ER) and coefficient of variation (CV), were obtained according to the following functions.

$$ER = VL^{-1}T^{-1} \qquad (1)$$

Where: *ER:* emission rate of pipe, L/ (m·h);

2.1. Coefficient of Variation

Small differences in manufacturing dropper cause many changes in the amount of output rate dropper is the issue of uniform distribution of irrigation water will have a negative impact. How to design technical and hydraulic dropper, quality formats used, the type of raw materials, parts casting technique and accuracy dropper applied on the most important factors in manufacturing stages build quality are a dropper.

$$CV(\%) = ({}^{S}/_{\bar{q}_i}) \times 100 \qquad (2)$$

$$S = \left(\frac{\sum_{i=1}^{n} q_i{}^2 - \frac{1}{n}(\sum_{i=1}^{n} q_i)^2}{n-1} \right)^{\frac{1}{2}} \qquad (3)$$

Where:

CV: variation coefficient of emission rate of pipe, %; *V*: volume of water emitted, L; *L*: length of porous pipe, m; *T:* time, h; $\bar{q}_i$: average flow rate of emitters, L/h; *S:* standard deviation of the emitter's flow rate; q_i: the i th emitter's flow rate, L/h, (i =1, 2,…, n); *n:* number of emitters.

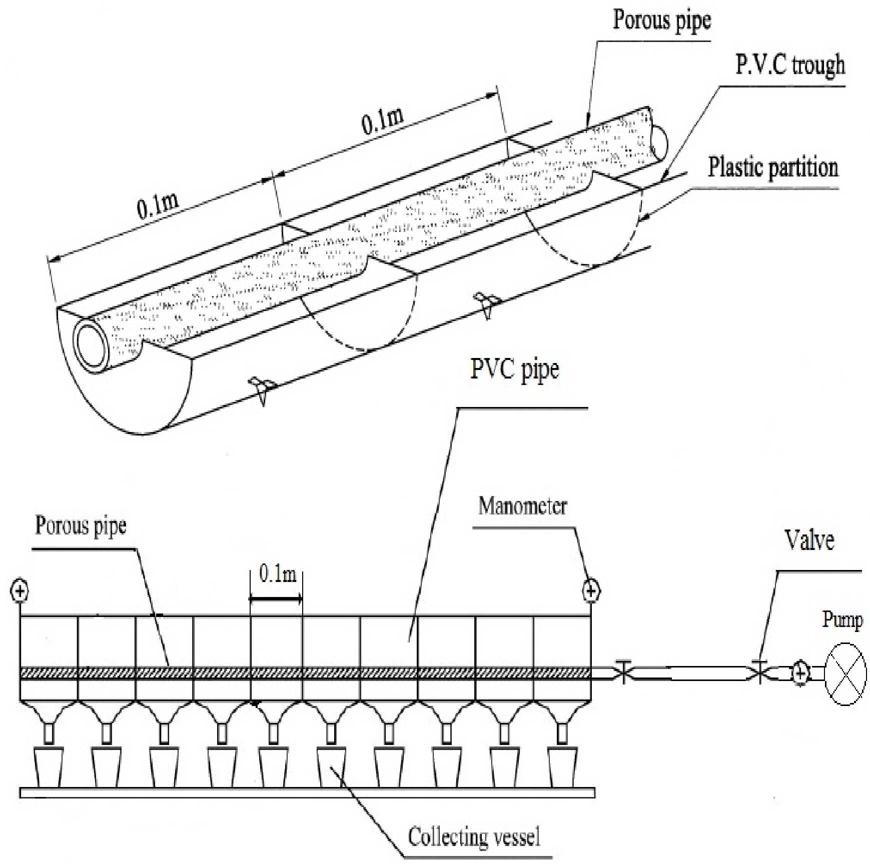

Figure1. Schematic diagram of the experimental set-up to assess the uniformity of water application of the porous pipe

3. RESULTS AND ANALYSIS

During initial discharge, emission rate of a porous pipe dropped drastically. In order to avoid an influence of the change on test results, in this study, a preliminary discharge for each pipe was tested repeatedly (three times in all, all time lasted 5 hours;) After that the porous pipe was tested under different pressures. Finally, repetitive tests for each pipe were carried out.

Flow patterns of the pipe segments under different pressures are presented in Figs 2, 3 and 4. The three replications showed different variation to the pressure, so they are presented individually. With the operating pressure increasing, emission rate of each pipe showed an increasing trend, however different part of the pipe showed different reaction to the increase in pressure. The values are the average value of emission rate measured at the time zero and after 20 minutes operation under the different pressures. The pipes were tested at 3.5, 7, 10.5, 14, 17.5 and 21 m pressure to evaluate the influence of pressure on variations of their discharge characteristics with time.

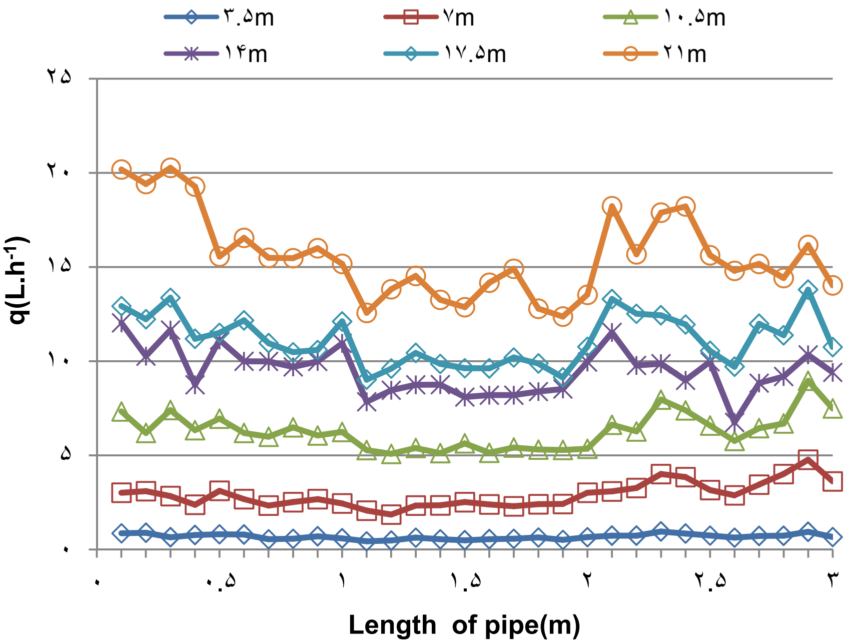

Figure 2. Flow patterns of pipe #1 at different pressures

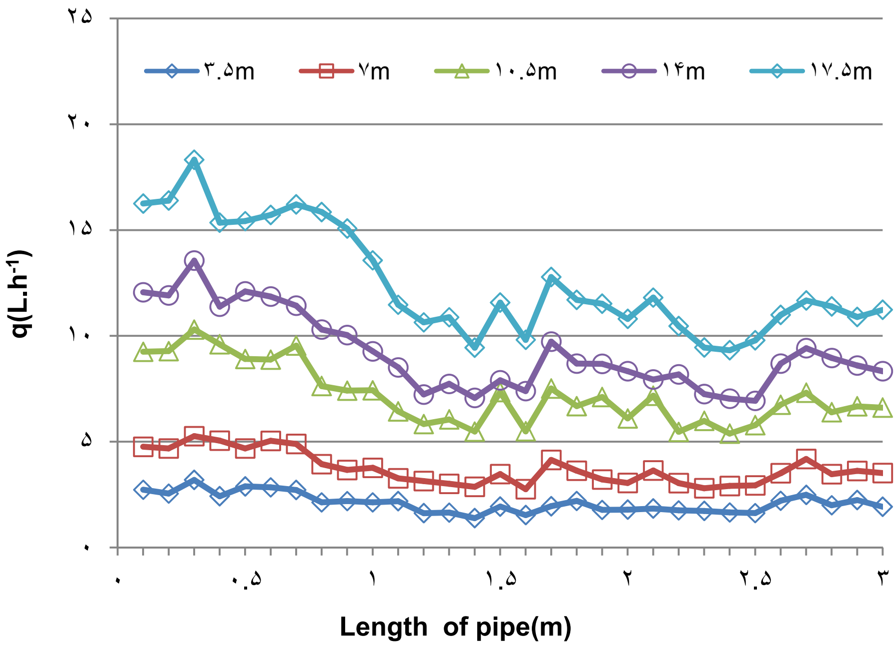

Figure 3. Flow patterns of pipe #2 at different pressures

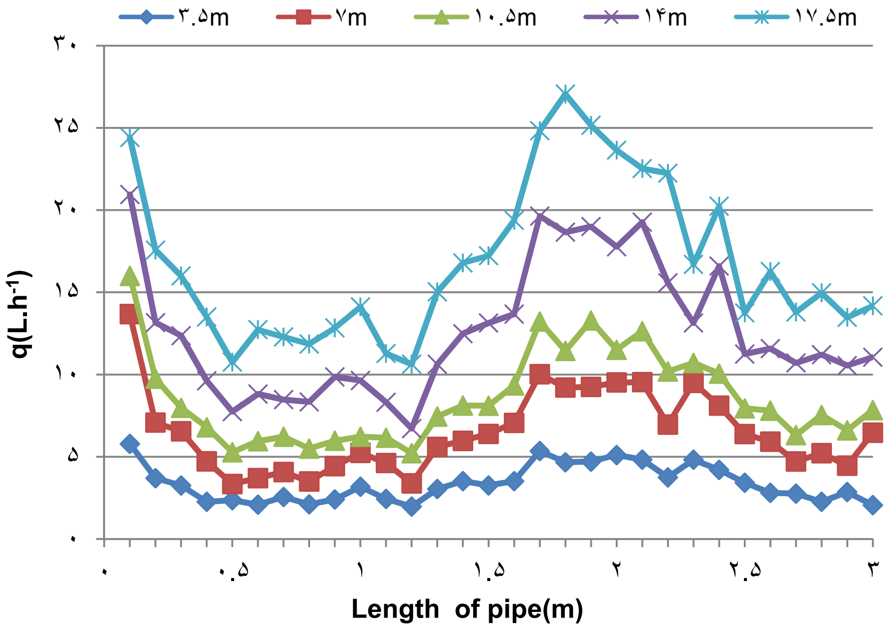

Figure 4. Flow patterns of pipe #3 at different pressures

Each test lasted after 8 hours. Fig.5, 6 and7 compares the initial and final flow rate of the pipes. During initial discharge, emission rate of a porous pipe dropped drastically. In each test, the discharge rate of each segment decreased gradually with time, which could also be seen by comparing the change of emission rate of a porous pipe (average of all the segments' flow rates for a pipe). Since distilled water was applied, the decrease could be attributed to structural changes in pipe matrix.

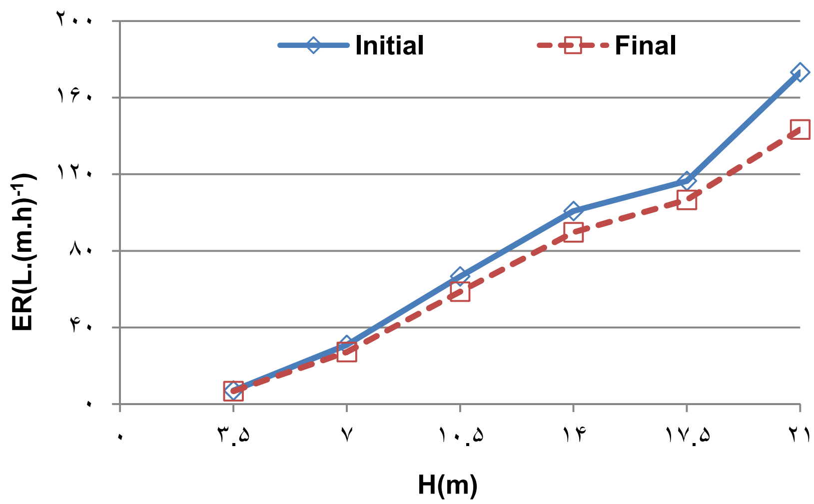

Figure 5. Changes of Initial and final emission rates (ER) with pressure (H) for pipe #1 at different pressures

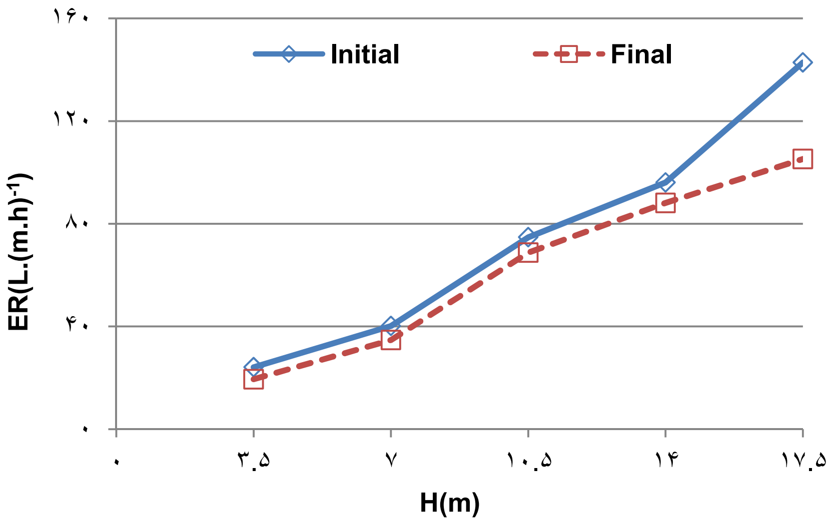

Figure 6. Changes of Initial and final emission rates (ER) with pressure (H) for pipe #2 at different pressures

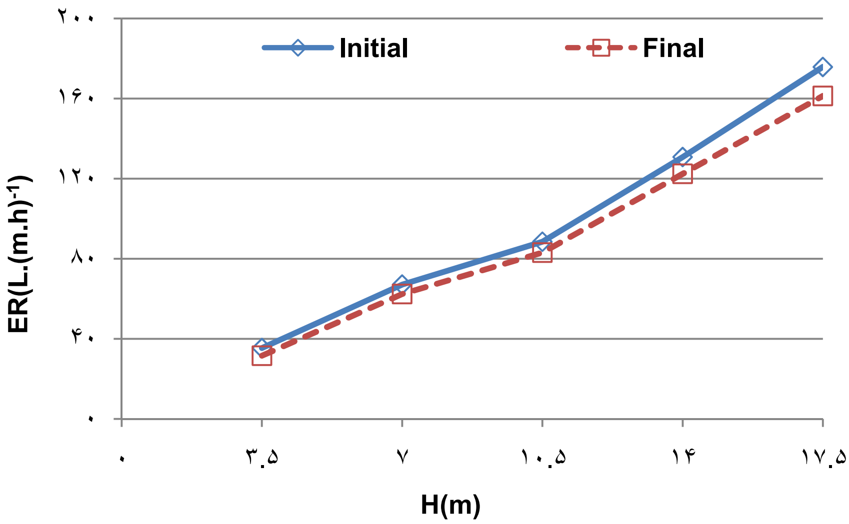

Figure 7. Changes of Initial and final emission rates (ER) with pressure (H) for pipe #3 at different pressures

3.1. Variation of Discharge Uniformity with Pressure

The effect of pressure on Coefficient of Variation (CV) is shown in Fig.8, 9,10 and11. With the operating pressure increasing, the CVs of each pipe first showed a decreasing trend. The test results indicated that the emission rate and discharge uniformity of each pipe varied with pressure significantly. Hence, any evaluation on discharge characteristics of this kind of porous pipe must consider operating pressure. According to the ASAE Standard EP405.1 for drip equipment (ASAE, 1989), a CV less than 10% is good, and between 10% and 20% is acceptable while above 20% is unacceptable for line-source emitters. The CV values obtained in this study suggested that only pipe #1 operating at pressure within 10.5 ～ 21m was in the acceptable range.

The results confirmed the fact that both emission rate and discharge uniformity of the porous pipes varied with operating pressure. But the differences of the parameters among the replicas are remarkable, indicating that the discharge characteristics of the porous pipes are unsteady.

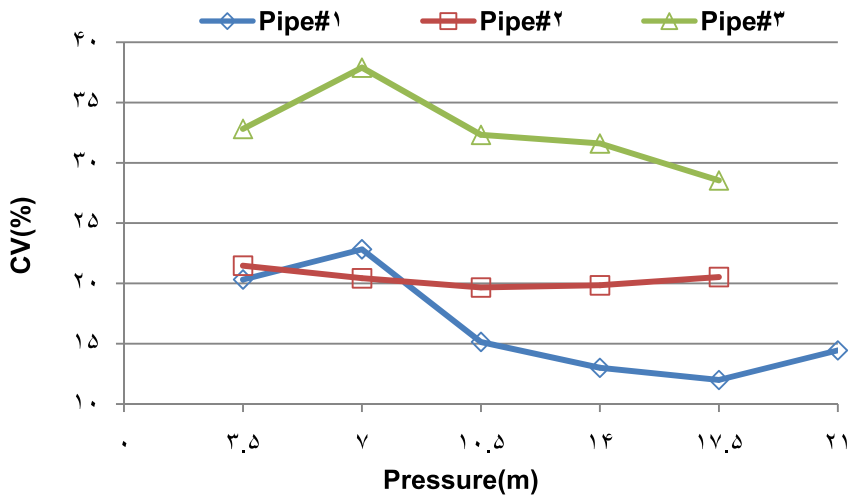

Figure 8. Changes in coefficients of variation of flow rate

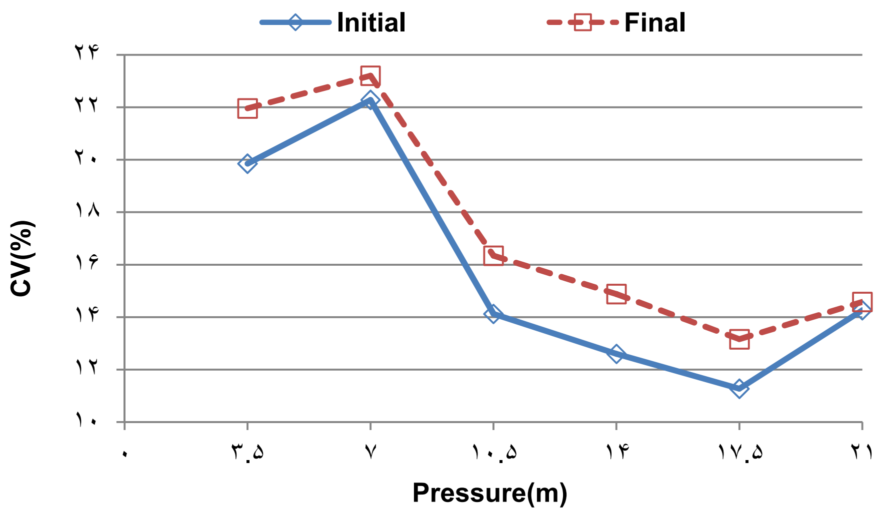

Figure 9. Changes in variation coefficient of flow rate during the tests at pipe#1

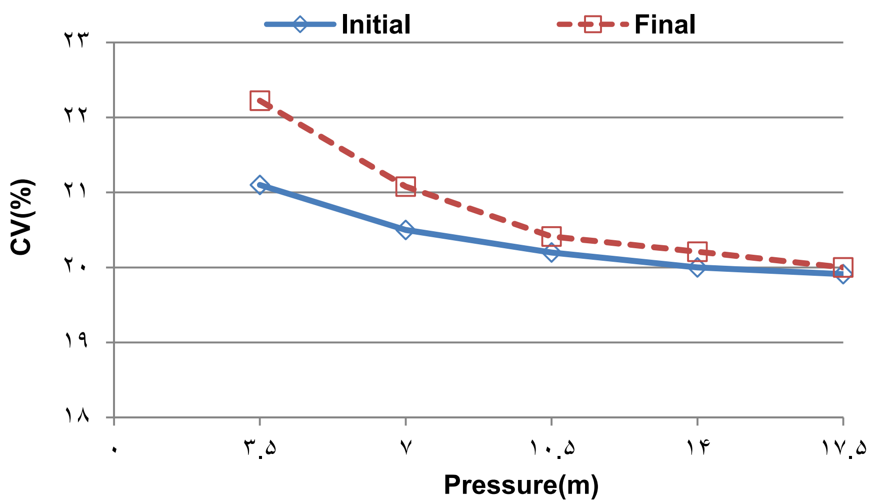

Figure 10. Changes in variation coefficient of flow rate during the tests at pipe#2

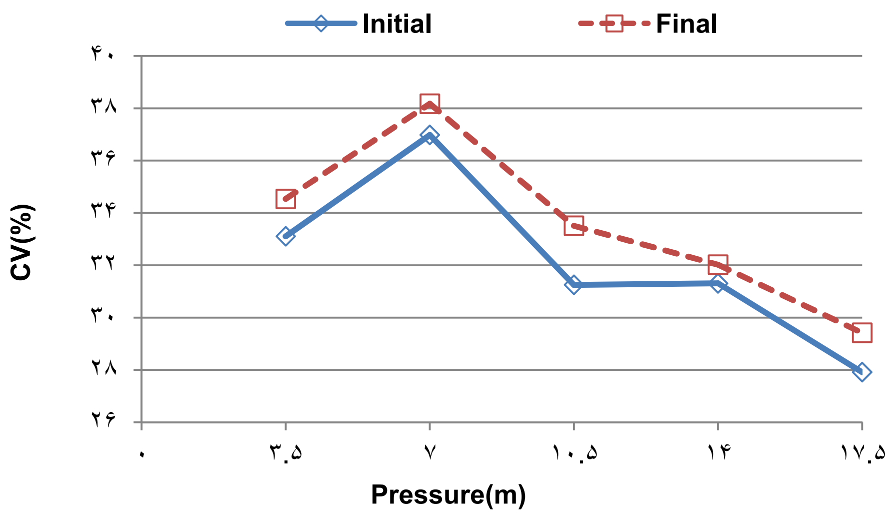

Figure 11. Changes in variation coefficient of flow rate during the tests at pipe#3

3.2. Pressure-Discharge Relationship

The emission rate is the average value of each pipe tested in the initial and final 20 minutes under the different pressures. Regression analysis between the emission rate (ER) and the pressure (H) showed that the two were related by a power and linear functions, i.e. $q=K_d.H^x$ and $q=K_d.H^x+k1$. K and x were constants for a particular porous pipe and dependent on units.

The test results indicated that the emission rate of each pipe varied with pressure. Compared with other emitters, the influence of pressure on the emission rate of the porous pipes was enormous, which could be found from the difference in discharge-pressure exponents between them. For many other emitters, such as various types of dripper and microjet made of non-elastic material polyethylene (PE), polyvinyl chloride (PVC), their discharge-pressure exponents range between 0.5 and 0.8(Capra and Scicolone 1998) But in this study, the exponents of the porous pipes are more than 1, which means that with the increase of operating pressure, after the value of H higher than 1, the emission rate of the porous pipes will increase drastically. Due to the flexibility of the pipe, the reasons mainly were that the increase of pressure accelerated the flow in each emission pore, enlarged pore dimensions, and also produced more effective emission pores (figures 12 to 17).

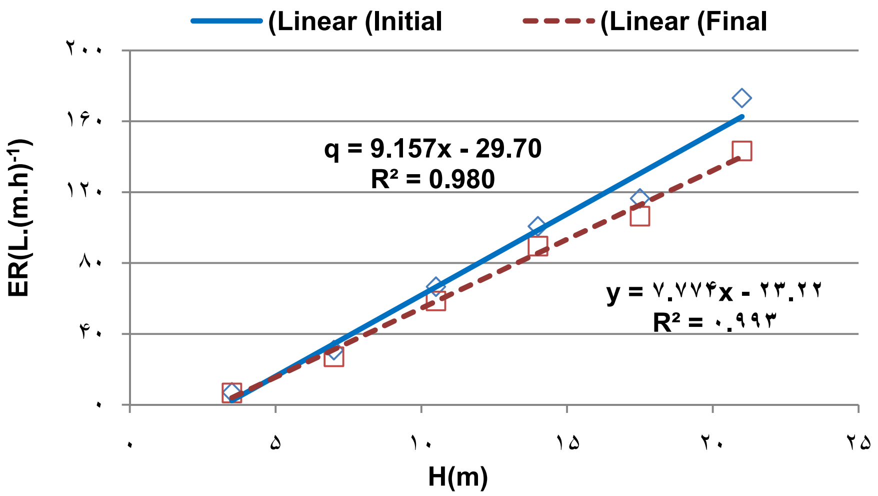

Figure 12. Linear regression analysis between the emission rate (ER) and the pressure (H) for pipe#1

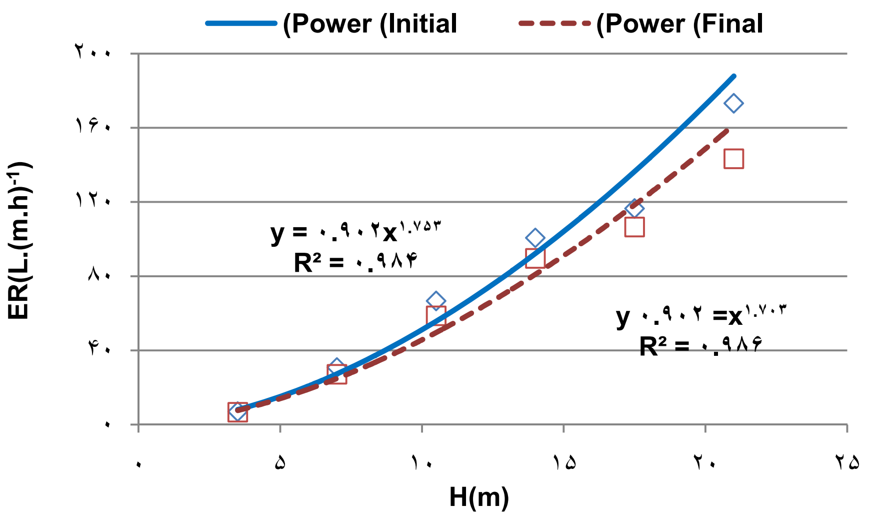

Figure 13. Power regression analysis between the emission rate (ER) and the pressure (H) for pipe#1

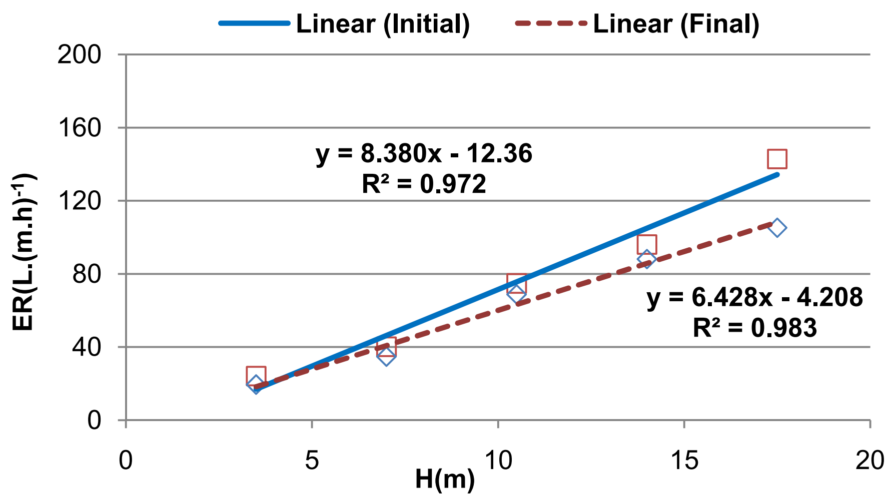

Figure 14. Linear regression analysis between the emission rate (ER) and the pressure (H) for pipe#2

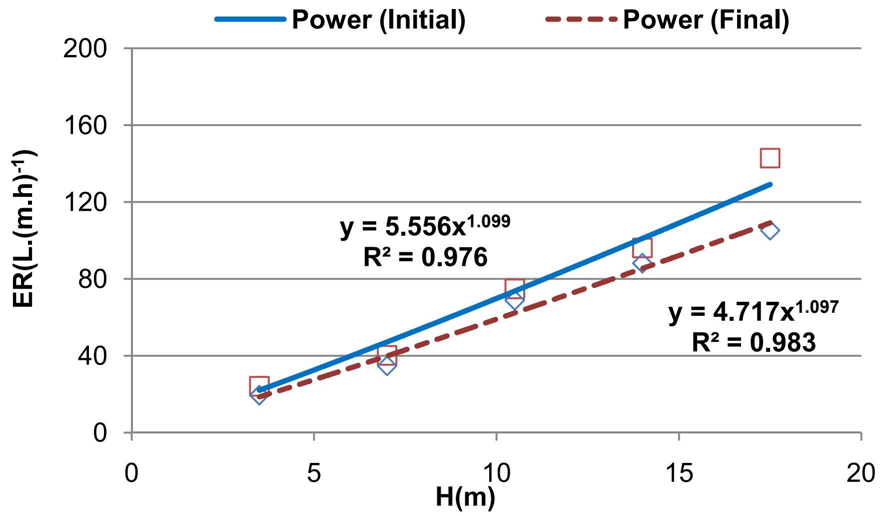

Figure 15. Power regression analysis between the emission rate (ER) and the pressure (H) for pipe#2

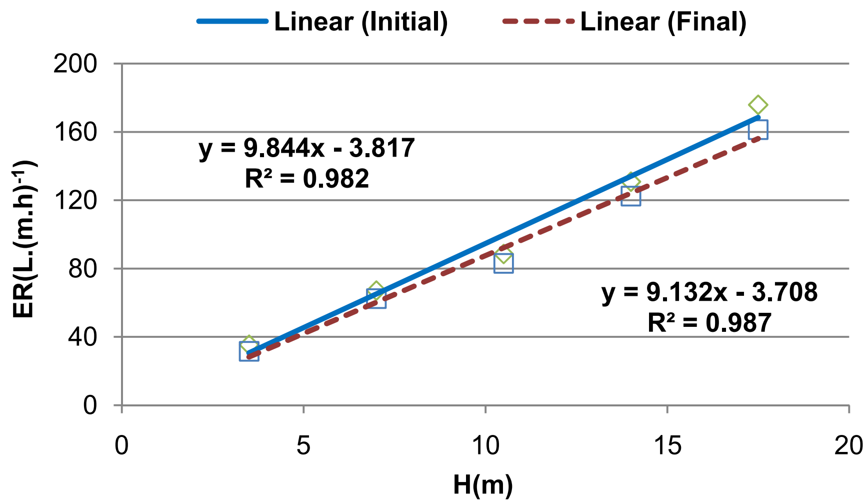

Figure 16. Linear regression analysis between the emission rate (ER) and the pressure (H) for pipe#3

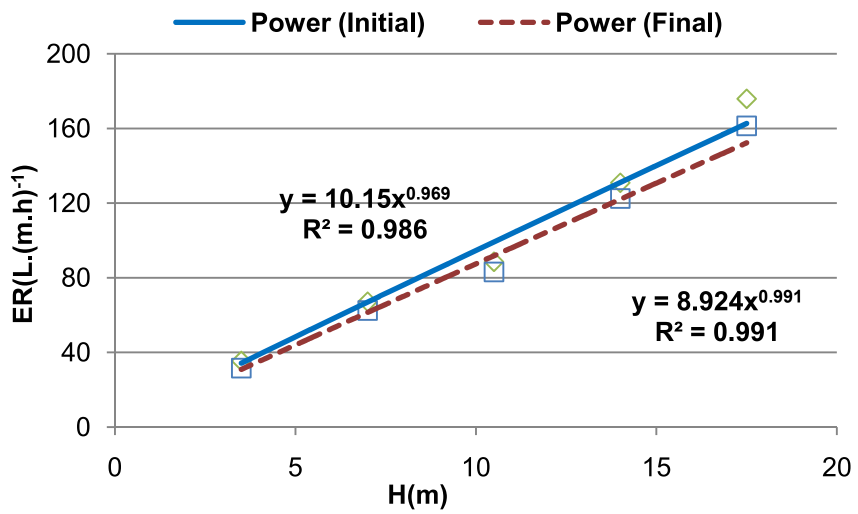

Figure 17. Power regression analysis between the emission rate (ER) and the pressure (H) for pipe#3

4. CONCLUSIONS

The study was conducted to investigate the effect of operating pressure on the discharge characteristics of porous pipe. The results could summarize as follows:

1) Operating pressure shows a significant influence on the discharge characteristics of porous pipe. Discharge-pressure exponent of porous pipe is more than 1, and discharge uniformity varies with pressure.

2) Under a certain pressure, the emission rate of a porous pipe decreases with time, initially drastically, then gradually to a stable state. But its Coefficient of Variation only fluctuates within a range. These variations are mainly due to the change in microstructure of the porous pipe.

3) More tests for porous pipes is suggested on porous pipe with longer than 3 m to provide some more practical information for direct field application of the pipe.

5. References

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