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# Evaluation of local head losses in drip irrigation laterals of inline emitters

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**ABSTRACT :** The study was conducted to evaluate the local head losses in drip irrigation laterals of inline emitters at M/s. Jain Irrigation Systems Private Limited by using the Hazen-Williams and Darcy-Weisbach equations. The emitters selected were Turbo Aqura at 4 L $h^{-1}$ emitter discharge with the lateral diameters of 12, 16 and 20 mm at 20, 40 and 60 cm dripper spacing, respectively under the operating pressure heads of 10, 8 and 6 m. The pressure head-distance relationships and local losses were evaluated for all the lateral types at three operating pressure heads of 10, 8 and 6 m. Flow discharges, pressure heads at various points on the laterals and the temperature of the water were measured during the study to determine their effect on the flow hydraulics in the drip laterals. The estimated local losses were in the range from 3.33 per cent (0.001 m) to 12.84 per cent (0.409 m) of the total head loss in the drip laterals at 10 m operating pressure head. Similarly, for the 8 and 6 m operating pressure head the local losses were in the range from 4.00 per cent (0.001 m) to 12.79 per cent (0.330 m) and 5.26 per cent (0.001 m) to 13.89 per cent (0.275 m) of the total head loss, respectively.

**KEY WORDS :** Drip irrigation, Discharge measurement, Frictional head loss, Local head loss

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The drip irrigation system uses pipes, tubes, filters, emitters or drippers and ancillary devices to deliver the water to specific sites at a point or grid on the soil surface. The water is distributed through small pressure dissipating devices called emitters mounted at predetermined intervals on relatively small diameter pipes called laterals. Drip system delivers the irrigation water directly to the crop root zone by minimizing the evaporation and infiltration losses with the increase in application efficiency. The drip irrigation design needs accurate evaluation of both the pipe friction loss and the loss due to the barb protrusion of the drippers into the laterals. Many researchers (Al Amoud, 1995; Juana *et al.,* 2002 and Reddy, 2003) highlighted the importance of considering local losses when more number of emitters are installed along the laterals. For inline emitters, local loss is due to the turbulence consequent to protrusion of emitter barbs into the flow, local losses are due to both the contraction and the expansion of flow stream lines at the emitter connections.

In a pressured irrigation system or any other hydraulic system including multiple outlets along the pipes, estimation of total friction head loss along a lateral requires a stepwise analysis starting from the lowest outlet, working upward and computing the head loss caused by friction in each segment (Mousavi *et al.,* 2011). The introduction of Blasius friction factor, into the Darcy-Weisbach equation provides an accurate estimation of the frictional losses produced by the turbulent flow inside uniform pipes with low wall roughness and when Reynolds numbers fall within the range of $3,000 < R < 100,000$. Most drip irrigation laterals are usually made of smooth polyethylene pipes and their flow regime fits these conditions (Juana *et al.,* 2002). Inline emitters cause the contraction and subsequent enlargement of flow streamlines due to the protrusion of emitter barbs into the flow (Provenzano and Pumo, 2004).

From the studies undertaken earlier, it can be observed that consideration of the emitter barb losses in the hydraulic design of trickle laterals will lead to more accurate prediction of head requirement for the trickle system. Hence, in this study, an attempt has been made to evaluate the emitter barb losses of different types of inline trickle irrigation laterals.

## METHODOLOGY

The experimental study was carried out to evaluate the emitter barb losses for the all the selected inline laterals with 4 L $h^{-1}$ dripper discharge at the different operating pressures 10, 8 and 6 m. The study was carried out in

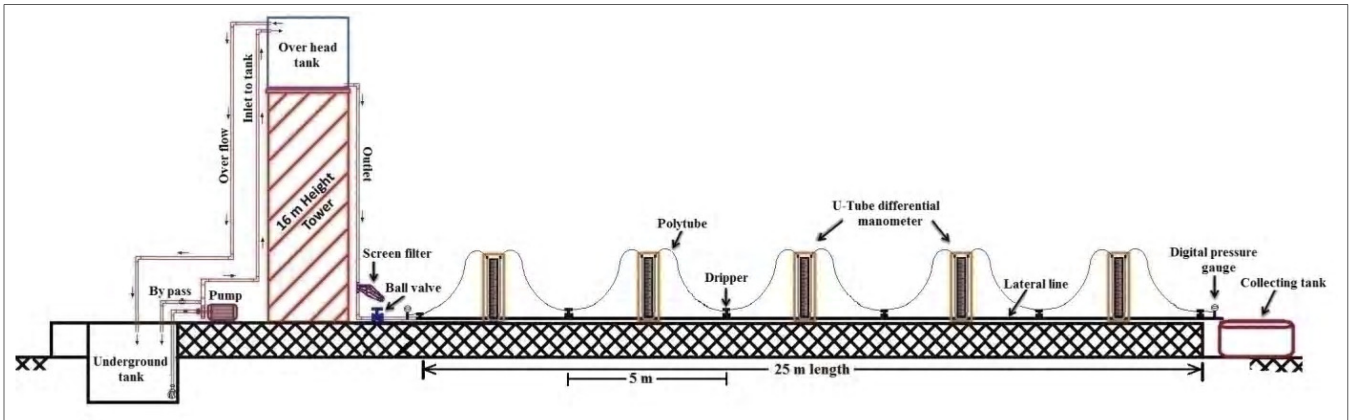


**Fig. A: Experimental lay-out of the study**

Department of Soil and Water Engineering at College of Agricultural Engineering, Raichur (Karnataka). The experimental lay-out (Fig. A) consisted of the two water tanks, 2.5 hp pump to lift the water, filters, pressure regulator valves, two digital pressure gauges, U-tube differential mercury manometers, vinyl tube, digital thermometer, water tank with piezometric tube and different types of experimental inline laterals as explained earlier.

In this experiment, the end of the lateral was closed to simulate a possible field condition. In each experiment, the flow was continued for 5 min or till the readings on the manometers gets stabilised for measuring the pressure heads. Then the observations were recorded. Outlet discharges of drippers were measured at a time interval of 3 minute, taking the actual water density into account. The precision of the outlet discharge was about ±1 per cent of the measured value. For each lateral the head losses were measured by five differential manometers at 20, 40, 60, 80 and 100 per cent of total length, respectively and two digital pressure gauges were connected at both the ends of the drip laterals. Each lateral was tested for three different operating heads of 10, 8 and 6 m. Temperature of the water during the experiment was measured with the help of the thermometer. Each experiment was replicated three times for reducing the experimental errors. Local loss co-efficient was measured by closing the dripper outlets with the help of M-Seal.

Friction losses of a small-diameter polyethylene pipe can be evaluated using the Darcy-Weisbach equation (Provenzano *et al.*, 2005) :

$$H_f = \frac{fLV^2}{2gD} \qquad \text{......(1)}$$

where,

$H_f$ = head loss due to friction, m

f = friction factor

L = length of lateral, m

V = mean flow velocity, m $sec^{-1}$

D = inner diameter of lateral, m

g = gravitational constant, m $sec^{-2}$.

The Darcy-Weisbach equation includes a dimensionless friction factor '*f*' that is a function of the Reynolds number and the roughness of the pipe. The friction factor can be expressed by an equation (Provenzano *et al.,* 2005) :

$$f = 0.302R^{-0.25} \qquad \text{......(2)}$$

where,

R = Reynolds number

f = friction factor.

Reynolds number is the ratio of the inertia force to viscous force. Reynolds number is given by following equation :

$$R = \frac{VD}{\upsilon} \qquad \text{......(3)}$$

where,

R = Reynolds number

V = velocity of flow, m $sec^{-1}$

D = inner diameter of lateral, m

$v$ = kinematic viscosity, $m^2$ $sec^{-1}$.

The value of dynamic viscosity for the measured temperature of water may be obtained from the following relationship :

$$\mu = \frac{0.0179}{1 + 0.03368T0.000221T^2} \qquad \text{......(4)}$$

where,

μ = dynamic viscosity of water, dyne-sec $cm^{-2}$

T = temperature of water, °C.

The relationship between dynamic viscosity and kinematic viscosity may be expressed as follows:

$$\vartheta = \frac{\mu}{\rho} \qquad \text{......(5)}$$

where,

υ = kinematic viscosity of water, $cm^2$ $sec^{-1}$

ρ = mass density of water, g $cc^{-1}$.

The local losses of energy are those which are caused on account of the change in the velocity of flowing fluid. In inline laterals, change in velocity occurs due to presence of emitters. The local loss per emitter is calculated as:

$$H_{Li} = \frac{P - H_f}{N} \quad ......(6)$$

where,

$H_{Li}$ = local loss per dripper, m

P = operating pressure head, m

$H_f$ = friction loss in lateral, m

N = total number of drippers.

The '$\alpha$' co-efficient can be estimated as a function of simple parameters such as acceleration due to gravity, local loss per dripper and velocity (Provenzano *et al.,* 2005):

$$H_{Li} = \alpha \frac{\upsilon_i^2}{2g} \quad ......(7)$$

Hence,

$$\alpha = \frac{2 \times g \times H_{Li}}{\upsilon_i^2} \quad ......(8)$$

where,

$v_i$ = mean velocity along the lateral immediately downstream of the (i+1)$^{th}$ emitter, m sec$^{-1}$

$\alpha$ = local loss co-efficient

g = acceleration due to gravity, m sec$^{-1}$.

The total friction losses between the first and the last emitter of the lateral, $H_f$, are calculated by using Hazen-William's formula as, (Al-Amoud, 1995) :

$$Hf = KL\left(\frac{Q}{C}\right)^{1.852} \frac{1}{D^{4.871}} \quad .......(9)$$

where,

$H_f$ = total estimated head loss, m

K = constant (1.22 x 10$^{10}$ for SI units)

L = length of lateral, m

Q = total discharge at lateral inlet, L sec$^{-1}$

C = Hazen Williams constant

D = inner diameter of lateral, mm.

Total local losses along a lateral $H_L$, in which N emitters are installed, can be similarly calculated as the sum of local losses $H_{Li}$, at the (i+1)$^{th}$ emitter, obtained considering outlet flow rate constant and equal to the nominal value, $q_{av}$. (Provenzano *et al*., 2005):

$$H_L = \sum_{i=1}^{N-1} H_{Li} = \alpha \frac{8}{g\pi^2} \frac{q_{av}^2}{D^4} \sum_{i=1}^{N-1} \left( [\![ i ]\!] \right)^2 \quad ...... (10)$$

where,

$\alpha$ = local loss co-efficient

$q_{av}$ = average discharge, L h$^{-1}$

D = internal diameter of lateral, mm.

Estimated total head loss along the lateral line '$H_{Te}$' is calculated by :

$$H_{Te} = Hf + HL \quad ......(11)$$

where,

$H_f$ and $H_L$ are estimated by using the above equations (Eq. 9 and Eq. 10)

Details of Turbo Aqura drip laterals are given in Table A.

**Table A: Details of Turbo Aqura (inline) drip laterals used in laboratory experiment**

| Sr. No. | Laterals | | Operating pressure head, m | Remarks |
|---|---|---|---|---|
| | Diameter, mm | Dripper spacing, cm | | |
| 1. | 12 mm lateral with closed drippers | 20 | 10, 8 and 6 | lateral end open |
| 2. | | 40 | 10, 8 and 6 | |
| 3. | | 60 | 10, 8 and 6 | |
| 4. | 12 mm lateral with open drippers | 20 | 10, 8 and 6 | lateral end closed |
| 5. | | 40 | 10, 8 and 6 | |
| 6. | | 60 | 10, 8 and 6 | |
| 7. | 16 mm lateral with closed drippers | 20 | 10, 8 and 6 | lateral end open |
| 8. | | 40 | 10, 8 and 6 | |
| 9. | | 60 | 10, 8 and 6 | |
| 10. | 16 mm lateral with open drippers | 20 | 10, 8 and 6 | lateral end closed |
| 11. | | 40 | 10, 8 and 6 | |
| 12. | | 60 | 10, 8 and 6 | |
| 13. | 20 mm lateral with closed drippers | 20 | 10, 8 and 6 | lateral end open |
| 14. | | 40 | 10, 8 and 6 | |
| 15. | | 60 | 10, 8 and 6 | |
| 16. | 20 mm lateral with closed drippers | 20 | 10, 8 and 6 | lateral end open |
| 17. | | 40 | 10, 8 and 6 | |
| 18. | | 60 | 10, 8 and 6 | |

## RESULTS AND DISCUSSION

The results obtained from the experimental studies conducted on different types of inline laterals with varying lateral diameters, dripper spacing and operating pressure heads for investigating the pipe frictional head losses and the local head losses due to protrusion of emitters along the length of the laterals are presented and analysed.

### Estimation of local loss co-efficient ($\alpha$) for the selected inline laterals :

The details of local loss co-efficient ($\alpha$) determined using the Eq. (8) for the various diameters of lateral, dripper spacing and at different operating pressure heads (Table 1). The effect of different factors of operating pressure head, temperature and discharge on local loss coefficient for various laterals is presented in Table 1. The local loss co-efficient value is used to measure the losses due to drippers in the drip laterals. These results are in agreement with the Provenzano and Pumo (2004) and Yildirim (2009) who also studied the local loss co-efficient ($\alpha$) value for few different drip lateral models, in which the local loss co-efficient ($\alpha$) value ranged from 0.297 to 0.671 with the commercially available dripper spacings of 0.2, 0.4, 0.6, 0.8, 1.0 and 1.5 m.

### Evaluation of frictional, local and total head losses along the 25 m length of the lateral at 10, 8 and 6 m operating pressure head :

The frictional and local head losses were determined with the eqns. 9 and 13 for all the different types of laterals with drippers of open outlet for various dripper diameters 20, 40 and 60 cm laterals, at different operating pressure heads of 6, 8 and 10 m. From the Table 2 to 5 predicted that, as the spacing of the dripper increases then the local head losses decreases and *vice versa*. The frictional head losses were

**Table 1: Local loss co-efficient (α) for Turbo Aqura (inline) laterals**

| Lateral diameter, mm | Dripper spacing, cm | Operating head, m | Tempe-rature, °C | Discharge (Q), $m^3/s$ | Local loss co-efficient ‘α’ |
|---|---|---|---|---|---|
| | | 10 | 38.3 | 0.000124 | 0.35 |
| | 20 | 8 | 38.3 | 0.000110 | 0.36 |
| | | 6 | 38.3 | 0.000092 | 0.40 |
| | | 10 | 38.2 | 0.000142 | 0.36 |
| 12 | 40 | 8 | 38.2 | 0.000123 | 0.40 |
| | | 6 | 38.2 | 0.000107 | 0.41 |
| | | 10 | 38.8 | 0.000142 | 0.42 |
| | 60 | 8 | 38.8 | 0.000127 | 0.44 |
| | | 6 | 38.8 | 0.000108 | 0.48 |
| | | 10 | 32.2 | 0.000303 | 0.15 |
| | 20 | 8 | 32.2 | 0.000269 | 0.14 |
| | | 6 | 32.2 | 0.000227 | 0.15 |
| | | 10 | 32.3 | 0.000323 | 0.17 |
| 16 | 40 | 8 | 32.3 | 0.000285 | 0.20 |
| | | 6 | 32.3 | 0.000242 | 0.20 |
| | | 10 | 34 | 0.000341 | 0.14 |
| | 60 | 8 | 34 | 0.000301 | 0.14 |
| | | 6 | 34 | 0.000253 | 0.22 |
| | | 10 | 31.8 | 0.000599 | 0.06 |
| | 20 | 8 | 31.8 | 0.000527 | 0.06 |
| | | 6 | 31.8 | 0.000446 | 0.07 |
| | | 10 | 31.3 | 0.000632 | 0.06 |
| 20 | 40 | 8 | 31.3 | 0.000562 | 006 |
| | | 6 | 31.3 | 0.000480 | 0.05 |
| | | 10 | 30.9 | 0.000648 | 0.06 |
| | 60 | 8 | 30.9 | 0.000562 | 0.08 |
| | | 6 | 30.9 | 0.000496 | 0.03 |

increased as the dripper spacing decreased along the length of the lateral line and *vice versa*. Hence, the dripper spacing and the frictional head losses are inversely proportional to each other of Turbo Aqura (inline) laterals of 12 mm diameter with dripper spacings of 20, 40 and 60 cm at 10 m operating pressure head, the friction and local head losses were ranged from 2.776 m (87.15% of total head loss) and 0.409 m (12.84 to 0.450 m (85.39%) and 0.076 m (14.42%), respectively. Similarly, the friction and local head losses were 0.753 m (91.16%) and 0.073 m (8.83%) to 0.102 m (92.72%) and 0.008 m (7.27%) for 16 mm lateral and 0.212 m (95.06%) and 0.011 m (4.93%) to 0.029 m (96.67%) and 0.001 m (3.33%) for 20 mm lateral, respectively (Table 2).

Similarly, for 8 m operating pressure head, the friction and local head losses were 2.249 m (87.17% of total head loss) and 0.330 m (12.79%) to 0.371 m (86.68%) and 0.057 m (13.31%). Similarly, the same for 16 mm lateral were 0.589 m (91.46%) and 0.055 m (8.54%) to 0.082 m (92.13%) and 0.006 m (6.74%) for 20 mm lateral were 0.173 m (95.05%) and 0.009 m (4.94%) to 0.024 m (96%) and 0.001 m (4%), respectively (Table 3).

Similarly, for 6 m operating pressure head, the friction

**Table 2 : Frictional head loss, local head loss and total head losses at 10 m operating pressure head**

| Lateral diameter, mm | Dripper spacing, cm | Frictional head losses, m | Local head losses, m | Total head losses, m |
|---|---|---|---|---|
| | 20 | 2.776 (87.15%)* | 0.409 (12.84%)* | 3.185 |
| 12 | 40 | 0.905 (87.94%) | 0.123 (11.95%) | 1.029 |
| | 60 | 0.450 (85.39%) | 0.076 (14.42%) | 0.527 |
| | 20 | 0.753 (91.16%) | 0.073 (08.83%) | 0.826 |
| 16 | 40 | 0.213 (91.02%) | 0.021 (08.97%) | 0.234 |
| | 60 | 0.102 (92.72%) | 0.008 (07.27%) | 0.110 |
| | 20 | 0.212 (95.06%) | 0.011 (04.93%) | 0.223 |
| 20 | 40 | 0.063 (95.45%) | 0.003 (04.54%) | 0.066 |
| | 60 | 0.029 (96.67%) | 0.001 (03.33%) | 0.030 |

* Percentage of the total head losses

**Table 3 : Frictional head loss, local head loss and total head losses at 10 m operating pressure head**

| Lateral diameter, mm | Dripper spacing, cm | Frictional head losses, m | Local head losses, m | Total head losses, m |
|---|---|---|---|---|
| | 20 | 2.249 (87.17%)* | 0.330 (12.79%)* | 2.580 |
| 12 | 40 | 0.730 (87.00%) | 0.108 (12.87%) | 0.839 |
| | 60 | 0.371 (86.68%) | 0.057 (13.31%) | 0.428 |
| | 20 | 0.589 (91.46%) | 0.055 (08.54%) | 0.644 |
| 16 | 40 | 0.173 (90.10%) | 0.019 (09.89%) | 0.192 |
| | 60 | 0.082 (92.13%) | 0.006 (06.74%) | 0.089 |
| | 20 | 0.173 (95.05%) | 0.009 (04.94%) | 0.182 |
| 20 | 40 | 0.052 (96.29%) | 0.002 (03.70%) | 0.054 |
| | 60 | 0.024 (96.00%) | 0.001 (04.00%) | 0.025 |

* Percentage of the total head losses

**Table 4 : Frictional head loss, local head loss and total head losses at 10 m operating pressure head**

| Lateral diameter, mm | Dripper spacing, cm | Frictional head losses, m | Local head losses, m | Total head losses, m |
|---|---|---|---|---|
| | 20 | 1.704 (86.06%)* | 0.275 (13.89%)* | 1.980 |
| 12 | 40 | 0.560 (88.18%) | 0.075 (11.81%) | 0.635 |
| | 60 | 0.286 (86.93%) | 0.042 (12.76%) | 0.329 |
| | 20 | 0.452 (91.12%) | 0.044 (08.87%) | 0.496 |
| 16 | 40 | 0.133 (89.86%) | 0.015 (10.13%) | 0.148 |
| | 60 | 0.063 (90.00%) | 0.007 (10.00%) | 0.070 |
| | 20 | 0.133 (95.00%) | 0.007 (05.00%) | 0.140 |
| 20 | 40 | 0.039 (97.50%) | 0.001 (02.50%) | 0.040 |
| | 60 | 0.018 (94.73%) | 0.001 (05.26%) | 0.019 |

* Percentage of the total head losses

and local head losses along the length of the lateral line were 1.704 m (86.06% of total head loss) and 0.275 m (13.89%) to 0.286 m (86.93%) and 0.042 m (12.76%) for 12 mm diameter, the friction and local head losses were 0.452 m (91.12%) and 0.044 m (8.87%) to 0.063 m (90%) and 0.007 m (10%) for 16 mm diameter, Similarly for 20 mm diameter the friction and local head losses were 0.133 m (95%) and 0.007 m (5%) to 0.018 m (94.73%) and 0.001 m (5.26%), respectively (Table 4).

The results obtained from the present experimental study are similar to Al-Amoud (1995) who observed the local head losses due to the barb protrusion of emitters was more than 32 per cent of the total head losses along the length of the drip lateral. Provenzano and Pumo (2004) also got the local head losses in the range of 33.1 and 49.5 per cent of the total head loss along the length of the laterals, for the different models of the emitters.

**Conclusion :**

- With increase in number of drippers and operating pressure head along the length of drip laterals, the local head losses also increased and *vice-versa,* indicating direct relationship between them.
- Further, as the diameter of drip lateral increased, the local head loss decreased along the length of the lateral and *vice-versa,* thus there was inverse relationship between them.
- The study on energy loss due to the connections of barb protrusions into the drip laterals had shown that there was a significant energy loss by the drippers. The energy loss due to the connections of drippers to the drip laterals was in the range from 3.33 to 12.84 per cent of the total frictional head loss at 10 m operating pressure head.
- Similarly, at 8 and 6 m operating pressure head the energy loss due to the connection of drippers was in the range of 4.00 to 12.79 per cent and 5.26 to 13.89 per cent of the total head loss, respectively. By considering the local loss into account it is possible to estimate the accurate head requirement for the design of the drip irrigation systems.

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