OnLine Journal of Biological Sciences 2 (3): 178-182, 2002

Water Saving Techniques Through Improved Water Distribution System in Deep Tubewell Area of Bangladesh

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Abstract: This study was undertaken at two locations in the central part of Bangladesh to assess the performance of PVC and plastic pipe water distribution system for command area development and irrigation time saving by minimizing water losses. In the system, total discharge from deep tubewell (DTW) was diverted to two or three directions by using PVC and plastic pipe of different lengths and diameters. Technical and economic feasibility of the system were also evaluated. The conveyance loss was 2.80 to 9.50% in PVC and plastic pipe whereas in earthen channel it varied from 30 to 33% in silty-clay loam soil, which indicates that on an average 83% water can be saved by improved pipe distribution system. The maximum pressure head in two-way flow condition was 4.25 m. The total head of DTW developed due to the pipe distribution system was 16.52 m at the peak irrigation period, which was below the limit of the total head of the DTW and did not create any problem on pump unit. The motor speed varied from 1490-1500 rpm in two-way or three-way flow conditions, which did not create any back-pressure on pump. By introducing the pipe distribution system about 37 to 41% command area was increased in both locations. The BCR of the pipe irrigation system varied from 2.74 to 1.43 on the basis of 15 to 45% discount rates. The partial pipe distribution system in DTW area was highly economical considering the BCR and IRR analysis.

Key words: PVC and plastic pipe, irrigation, distribution system, deep tubewell, water savings and economics

Introduction

Bangladesh has about 14.2 million hectares of cultivable land, out of which about 41 per cent land is brought under irrigation (BBS, 1998) by 528,335 STWs, 32,135 DTWs, 62,351 LLPs and other traditional methods (NMIDP, 1997). This low irrigation coverage is not only due to lack of development of irrigation facilities but also due to poor on-farm water distribution and management practices of the existing facilities.

Proper water distribution system and its efficient management play a very important role in the command area development of any irrigation project. In Bangladesh, use of earthen open channel for water distribution is common in minor irrigation sectors. These earthen open channel distribution systems suffer from a number of problems, for example, low conveyance and application efficiency, less area coverage and high maintenance cost. It is fact that open channel distribution system confronts some physical obstructions such as natural drainage channels or khals, embankment or road, high land, irregular or fragmented topography and permeable soils where canals suffer high seepage, leakage and evaporation losses and right of way problem. About 50% water losses through leakage and seepage and percolation, which is called conveyance loss (Biswas *et al.*, 1984). The conveyance loss not only reduces the irrigation coverage but also increases operating hours. As a result fuel cost and water tax are increased. Another disadvantage of open channel system is that about 2 to 4 percent of the cultivable land is taken up by the open channel distribution system (Michael, 1987). For uneven or fragmented topography and light textured soil, compaction is ineffective and channels require seasonal reconstruction, which needed lined channels system. But lined channel system is a costly affairs are easily undermined by erosion of the embankment. Buried pipe, PVC and flexible hose pipe distribution system may be the best solution for overcoming those problems. But buried pipe distribution system is also costly and needed the technical personnel for installation.

Planners, administrators and donor agencies seem to be shifting attention from building new irrigation systems to improving the performance of the existing system. Hence, there is a need to develop practical methodologies to upgrade the performance of the existing irrigation systems and thereby achieve higher benefits from the use of irrigation water. Construction of improved (compacted) earthen channels with necessary water control structures such as checks, diversions, culverts, siphons, aqueducts or short length of highly embanked channels and strengthening operation and maintenance capabilities can improve the performance of irrigation system in plain topography having fine textured soil. For uneven topography and coarse textured soil, earthen channel is ineffective therefore expensive lined channel need to be constructed.

Buried pipe water distribution system has some clear advantages and benefits over the open channel water distribution system. However, unsatisfactory jointing methods and techniques, frequent leaks, faulty outlet valves, spillage from air vents and high costs are associated with the system. All of the advantages of the buried pipe water distribution system are also applicable to the PVC and plastic pipe water distribution system. It is not necessary to install the PVC and plastic pipe system on a permanent basis. The pipeline system is essentially water tight with almost no conveyance and evaporation loss during transmission. There is a considerable amount of water savings, which reduces pumping cost. The PVC and plastic pipe method of water distribution system requires a less investment than an unlined or lined open channel and buried pipe system. This method is usable with buried pipe system or from the tubewell outlet directly (Bentum *et al.*, 1995). PVC and plastic pipe method of water distribution system is especially important in T. Aman season for supplemental irrigation because most of the earthen channels are not in usable condition after rainy season.

Because of many advantages, the PVC and plastic pipe method of water distribution system has wide applicability for irrigation in Rabi season and supplemental irrigation in T. Aman season. PVC pipe is also used to irrigate to some extent the undulated sugarcane land in the northern part of Bangladesh. But a systematic evaluation of the performance of this type of water distribution system in the farmers' field is still lacking. Therefore, this study was undertaken to evaluate the performance of the PVC and plastic pipe method of water distribution system in two deep tubewells (DTWs) located at Gazipur Sadar and Kapasia Upazilas of Gazipur district focusing on the water losses, irrigation time savings, command area development, technical and economic feasibility of the system.

Materials and Methods

The study was conducted during 1999-2000 at Biprobartha village of Gazipur Sadar Upazila and during 2000-2001 at Dashunarayanpur village of Kapasia Upazila under Gazipur district. In this study, PVC and plastic pipe water distribution systems were introduced in the DTWs. Total discharge from the DTW is diverted to two or three directions by using PVC and plastic pipes of different lengths and diameters. To divert the flow in different directions PVC and plastic pipe of different lengths, PVC cross, bends, tees and other necessary fittings were used. PVC cross was fitted with the outlet of the pump with reducer. Different diameter PVC and plastic pipes were fitted with the cross to distribute the irrigation water to the desired locations. The flow diagram of PVC and plastic pipe water distribution system is illustrated in Fig. 1.

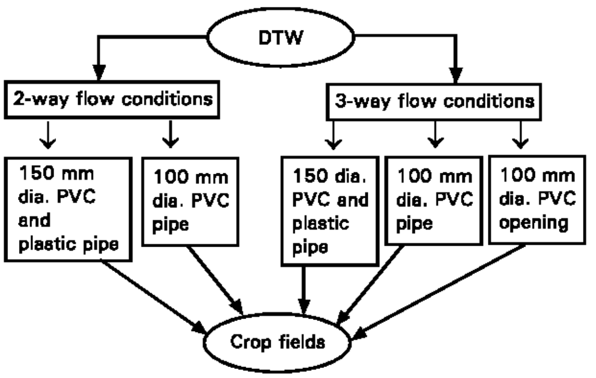

Fig. 1: Flow diagram of PVC and plastic pipe distribution system

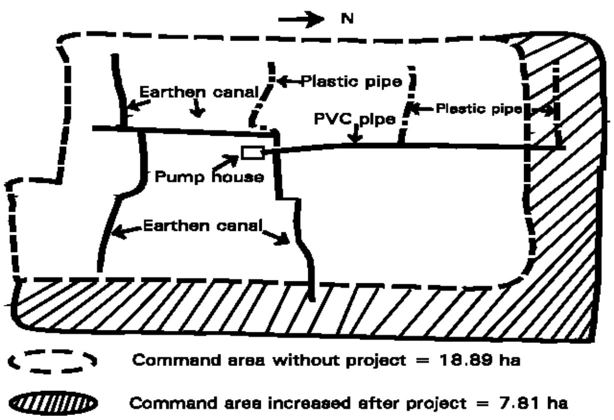

Fig. 2: Command area development by PVC and distribution system at Biprobartha, Gazipur

A benchmark survey was done to collect the basic information in both sites before installation of the system. Problems arises during the operations were identified in discussion with the pump managers, pump operators and the local farmers and decided, which one was the most problematic area. According to the reconnaissance survey information and their choice, a partial PVC and plastic pipe water distribution system were installed in both sites to achieve the objective of the study. Discharge, conveyance losses, command area development and technical and economical data were taken for evaluation of the system.

Discharge and conveyance loss: The discharge of the tubewell outlet was measured by using a cut-throat flume and the discharges of the PVC and plastic pipe outlets were measured by the volumetric method. Readings were taken thrice to obtain average discharge. Initially, the water was allowed to flow in three directions through the cross. One outlet was closed to observe its impact on discharge and motor speed.

The conveyance loss was measured by using inflow-outflow method. In this method, two standard cut-throat flumes of size 91.44 x 20.32 cm^2 were used. One of the flumes (flume 1) was set in a channel near the outlet of the DTW or to the outlet of the PVC and plastic pipe and the other flume (flume 2) was set at a known distance apart in a straight channel section. The flume readings were taken simultaneously when steady flow occurred in the channel. From the known flume discharges and the distance between the flumes, the loss of water per 100 m was calculated using the following relationship (Rashid *et al.*, 1991):

$$CL = [(Q_1 - Q_2) / L] \times 100 \text{---------------------} (1)$$

where, CL = water loss in the channel, l/s/100 m
Q_1 = discharge in flume 1, l/s
Q_2 = discharge in flume 2, l/s
L = distance between the flumes

Pressure head at different points of the PVC and plastic pipe distribution system was measured by using the different sizes manometer for variable discharges and flow conditions. Speed of the engine/motor for different flow conditions was measured in revolution per minute (RPM) by using a tachometer. SWL and PWL of the tubewell were measured in every week by using a electric depth gauge. Monthly average SWL and PWL was calculated from the weekly data.

Details of irrigated areas under the deep tubewells for the study period were collected from the manager of the respected schemes. Irrigated areas under PVC and plastic pipe method of water distribution systems were estimated through interviewing the manager as well as the respective land owners. The total irrigated area under the schemes was also measured. The command area before and after the use of PVC and plastic pipe are shown in Figs. 2 and 3.

Economic analysis: Based on costs and returns from the pipe irrigation system, an economic analysis was carried out for the pipe system in order to ascertain the profitability of the technology. For this purpose discounting method of the project appraisal technique was used. By discounting future cash flows are reduced to their present worth. For measuring the relative worthiness of the system, the Net Present Worth (NPW), Benefit-Cost-Ratio (BCR) and Internal Rate of Return (IRR) were calculated based on the different discount rates.

The per hectare project benefit was estimated by taking the differences between the net returns per hectare due to pipe irrigation system weighted by the proportions of the respective crop areas in relation to the gross cropped areas. The per hectare annual benefit for the terminal year of the project, the per hectare salvage value was added to this benefit. The per hectare annual benefit, thus estimated, was converted into annual project benefit on the basis of increased command area. The costs included in the above calculations were initial investments, replacement cost and operating capital requirements for pipe irrigation. In this study, it was assumed that the life spans of PVC and plastic pipe were 20 and 5 years, respectively. The given discount rate was 15%.

Results and Discussion

Deep tubewell discharge: The total tubewell discharges were found 42.50 lit/sec and 47.12 lit/sec in Biprobartha and Dashunarayanpur village, respectively (Table 1). By using PVC and plastic pipe the discharge varies from 11.15 lit/sec to 27.84 lit/sec compare to 19.27 lit/sec to 24.00 lit/sec in earthen channel.

Conveyance loss of the pipe system: The conveyance losses in different flow conditions in different pipe lines in both locations varies from 0.62 to 1.83 lit/sec/100 m i.e. from 2.80 to 9.50% and that in earthen channel was varied from 5.72 to 7.92 i.e., from 30 to 33% (Table 2). Maniruzzaman *et al.* (2000) reported that the conveyance loss in 100 mm diameter hose pipe varied from 0.14 to 0.42 lit/sec/100 m with an average of 0.29 lit/sec/100 m for irrigation water distribution at Nakla and Sreebordi Upazilas of Sherpur district, Bangladesh. This is an agreement with Rashid *et al.* (1991), who found that water losses were 9 lit/sec/100 m in farmers built open channels and 7 lit/sec/100 m in improved (compacted) earth channels in Manikganj district, Bangladesh. Water loss in pipe system occurred due to leakage and for some faulty and loose jointing. It should be mentioned that the soil and land type of different locations are almost same. The soil in the study sites was silty-clay loam in texture and undulating in topography. These results are in agreement with the findings of FAO (1988). The conveyance losses of different distribution system at different locations of Gazipur district are given in Table 3, which reveals that by partial PVC and plastic pipe distribution system on average about 83%

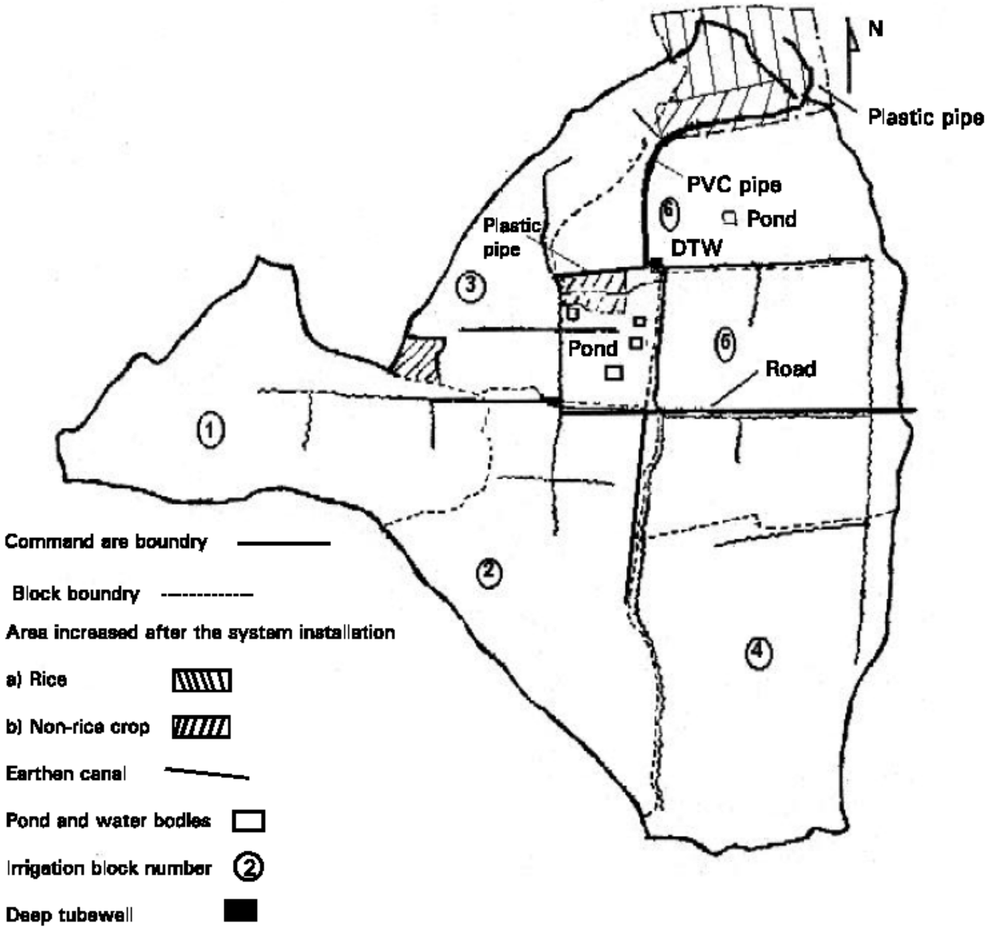

Fig. 3: Command area development by PVC and plastic pipe distribution system in a DTW at Dashunarayanpur, Kapasia

Table 1: Discharges of different pipes and earthen channel in different flow conditions

Locations	Flow condition	Total pump discharge (lit/sec)	Av. discharge in different line	
			Line*	Discharge (lit/sec)
Biprobartha	Line A, B open and C closed	42.50	A (PVC and plastic pipe)	18.50
			B (Earthen channel)	24.00
Dashunarayanpur	Line X, Y and Z open	47.12	X	11.15
			Y	16.70
			Z (Earthen channel)	19.27
	Line X, Y open and Z closed	47.12	X	19.28
			Y	27.84

*Line A = 150 mm dia. PVC pipe 122 m, 100 mm dia PVC pipe 60 m and 100 mm dia plastic pipe 152 m. Line B &C = 100 mm dia. openings at the cross Line X = 150 mm dia. PVC pipe 122 m, 150 mm dia plastic pipe 150 m and 125 mm dia plastic pipe 190 m. Line Y = 100 mm dia. PVC pipe 60 m Line Z = 100 mm dia. opening at the cross

Table 2: Conveyance losses under different distribution systems and flow conditions

Locations	Flow conditions	Total pump discharge (lit/sec)	Av. discharge in different line		Conveyance loss			
			Line	Discharge (lit/sec)	PVC & Plastic pipe		Earthen canal	
					l/s/100m	%	l/s/100m	%
Biprobartha	Line A, B open and C closed	42.5	A (PVC and plastic pipe)	18.50	1.26	6.8	-	-
			B (Earthen channel)	24.00	-	-	7.92	33
Dashu-narayanpur	Line X, Y and Z open	47.12	X	11.15	1.02	9.15	5.72	30
			Y	16.70	0.62	3.71		
			Z (Earthen channel)	19.27	-	-		
	Line X, Y open and Z closed	47.12	X	19.28	1.83	9.50		
			Y	27.84	0.78	2.80		
	Average				1.06	6.3	5.72	30

Table 3: Comparative water savings between PVC & plastic pipe and earthen channel distribution systems

	Conveyance loss (lit/sec/100 m)		
Locations	PVC and plastic pipe	Earthen channel	% water saved by PVC and plastic pipe
Biprobartha	1.26	7.92	84
Dashunarayanpur	1.06	5.72	81
Average	1.16	6.82	83

Table 4: Discharges and pressure head of different pipes in different flow conditions at Dashunarayanpur

Flow conditions	Line	Discharge (lit/sec)	Maximum pressure head (m)	Motor speed (RPM)	Remarks
Line X, Y and Z open	X	11.15	2.43	1490-1500	No difference in motor RPM was found
		Y	16.70	0.60	
	Z	19.27	-		
Line X , Y open and Z closed	X	19.28	4.25	1490-1500	
	Y	27.84	1.85		

Table 5: Static and pumping water level in different time at Dashunarayanpur in Boro season, 2001

Date	Static water level (m)	Pumping water level (m)	Drawdown (m)
January	3.42	-	-
February	4.26	9.76	5.50
March	5.37	11.00	5.63
April	5.84	11.76	5.92
May	6.15	12.27	6.12
June	4.74	10.33	5.59
July	3.64	-	-
August	2.16	-	-

Table 6: Command area increased at two locations after installation of the system

		Irrigation coverage (ha)		
Locations	Potential command area (ha)	Without the system	With the system	Command area increased (%)
Biprobartha	32	18.89	26.70	41
Dashunarayanpur	32	16.00	22.00	37

Table 7: Comparative costs of the different distribution systems

Distribution systems	Estimated cost (Tk./m)
Brick lining i.e., lined canal	765
Unimproved earthen channel	140
Improved (compacted) earthen channel with control structure	240
Pre-cast semicircular	481
In-situ semicircular CC pipes	656
CC buried pipe (250 mm)	378
uPVC buried pipe (Class C pipe, 150 mm)	850
PVC pipe (Ordinary, 150 mm)	300
Plastic pipe (150 mm)	65

Table 8: Annual direct benefit per ha from improved distribution system at Dashunarayanpur

Crops	Per ha direct benefit (Tk.)	Increased area (ha)	Annual benefit * (Tk.)
Boro	4156	3.50	14546
Banana	11227	1.50	16840
Sugarcane	16810	1.00	16810
Annual benefit*	-	-	48196
Salvage value**	-	-	6755
Annual benefit***	-	-	54951

* Annual benefit in each year other than terminal year of the project
** Assume 10% of initial capital investment *** Annual benefit of the project at the terminal year.

Table 9: Net present worth and benefit cost ratio of pipe irrigation system at Dashunarayanpur

Investment criteria	Discount rates (%)			
	15	25	35	45
Net present worth (Tk.)	165374	78437	39152	18815
Benefit cost ratio (BCR)	2.74	2.08	1.63	1.43

water could be saved over the earthen channel. It was possible due to reduction of conveyance loss from 6.82 to 1.16 lit/sec/100 m by using pipe distribution system. This is also an agreement with Maniruzzaman *et al.* (2000), who found that about 95% of the water lost in the earthen channel was saved by using hose pipe (100 mm diameter) method of water distribution system from STW.

Pressure head and engine/motor speed: The maximum pressure head was 4.25 m in two-ways flow condition (Table 4). In farmers field 2 to 3 stages pump normally used in DTW. The total head of a DTW varies from 24 to 37 m. The maximum pumping water level was found 12.27 m (Table 5), so the total head i.e., pressure head and pumping head at peak irrigation season becomes 16.52 m, which was below the limit of the total head and did not create any problem in DTW operation.
The RPM of motor for different flow conditions for the PVC and plastic pipe network were 1490-1500 (Table 4). This slight variation in RPM occurred due to the fluctuation of the electric voltage and almost same in both flow conditions, which indicated that there was no back-pressure occurred in partial pipe networking.

SWL and PWL: The static water level (SWL) data indicated that the water level slightly falls in peak irrigation season, but it recovered during monsoon after end of the dry season, which indicated that the aquifer was fully recharged.

Irrigation coverage by the pipe system: The command areas of the selected DTWs are comprised with undulated land, roads, homestead and some depressed areas. The irrigation coverage before the system installation in Biprobartha and Dashunarayanpur were 18.89 and 16 ha, respectively though the potential command area of both the DTWs were 32 ha (Table 6). Due to topographical problems, construction of earthen field channel was difficult. So, introduction of pipe irrigation system was performed well in those selected areas. By using the technology, 7.81 ha of un-irrigated area was brought under irrigation facilities during Boro season, 2000 at Biprobartha. The command area increased at Dashunarayanpur was 6 ha (i.e., 3.5 ha rice, 1.5 ha of banana garden, and 1 ha of sugarcane) during Boro season, 2001. Due to newly irrigation coverage, the command area was increased from 18.89 to 26.70 ha (41%) at Biprobartha and that from 16 to 22 ha (37%) at Dashunarayanpur (Table 6). The achievement of the technology in developing command area at different locations of Gazipur district during Boro seasons is shown in Table 6. Maniruzzaman *et al.* (2000) found that the command area increased by 40 to 50% by using hose pipe in STWs at Nakla and Sreebardi Upazilas of Sherpur district. Note that in all locations only a portion of the whole earthen channel distribution system was replaced by pipe system. Replacement of the whole earthen channel distribution system by the pipe system would increased considerable command area and thereby minimize irrigation costs.

Saving of operating time: Conveyance loss, conveyance and irrigation time in PVC and plastic pipe system were lower than the earthen channel system. It was observed that about 47 to 55% of time saved by using PVC and plastic pipe compared to earthen channel and consequently save the fuel & oil, labour and money and also to increase the command area.

Comparative cost: Per meter cost of different distribution systems are shown in Table 7, which reveals that per meter cost of brick lining was Tk. 765 while it was Tk. 300 for PVC pipe (dia. 200 mm). The above cost outlined showed that PVC and plastic pipe method of water distribution system was lower than other improved distribution systems.

Economic analysis: The estimated per hectare annual benefit and total project benefit from improved irrigation system (pipe irrigation) are presented in Table 8, which reveals that the per hectare annual benefit with and without salvage value were Tk. 54,951 and Tk. 48,196 respectively. Project cost, on the other hand, is the value of goods and services used to establish, maintain and operation a project" (Eckstein, 1958). In this study, project costs included initial investment capital (PVC and plastic pipe) cost (Tk. 67,550), operation and maintenance cost (Tk. 3000/yr.) and replacement cost of plastic pipe (after every 5^{th} year, Tk. 19,250).

The NPW and BCR of the system were determined assuming different discount rates. The investments on pipe irrigation was highly economically viable and profitable over 45% discount rate (Table 9). The calculated IRR was over 50%, which also indicates that the investment on pipe irrigation was highly benefited.

Conclusions and planning implications: The partial PVC and plastic pipe method of water distribution system can be saved about 83% water compared to the earthen channel and increased the command area about 40%. This system can be applicable in two-way or three-way flow conditions, without creating any back-pressure impact on the pump. The system becomes highly economic considering the BCR and IRR analysis up to the discount rate of 45%. But the initial investment cost of the system is high. Therefore, individual farmers or tubewell owner may not interested to install the system. So, installation of the system is a precondition for deriving benefit from the improved distribution system. Thus, the government or NGO's should take the necessary arrangements to promote the system. If the system becomes more effective and popularized among the farmers, existing command area of DTW will be increased sharply and consequently increased the national production and income.

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