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Farm Ponds Lining Materials - A Review Article

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A B S T R A C T

Rainfed agriculture can be protected by adopting farm ponds. The harvested runoff water in a farm pond creates salinization / water logging problems so, it has to be lined to control the seepage losses. The article presents a review on the type of lining materials viable and to explore for a cost effective sealant which can be adapted. In comparison to clay lining, bentonite, LDPE and HDPE, HDPE in combination with concrete increases the durability along with the 100% seepage control with benefit cost ratio for HDPE lining in combination with concrete showed highest value of 10.4:1. Bentonite, though costly has shown significant results by reducing the seepage losses by 72% to 96% respectively, depending on the thickness of application. In vertisols, lining did not show any significant variation. Whereas alfisols, luvisols of arid and semi-arid regions require lining materials with diversified crops and conservative irrigation practices.

Introduction

Global warming is evidencing the present rainfall scenarios like extreme drought or heavy showers for short duration, means though the annual rainfall is normal water will not be sufficient for rainfed agriculture. Rainfed agriculture provides subsistence to Indian farmer which is inadequate and uncertain (Bhandarkar, 2009). The rate of infiltration of rain water depends on the texture and structure of the soil. Though the percolated water will rejuvenate ground water storage it cannot be allowed as it takes more time where immediate irrigation requirements are to be met. Therefore on farm water conservation and storage practices (Vohland and Barry, 2010) at low cost are to be adopted depending on the local climatic conditions (Palmier *et al.*, 2010). Arid and semi-arid regions are hardly secured to kharif crop production due to prolonged dry spells in *kharif* season.

The historical study can be used for designing the conservation practices. Runoff water can be conserved through insitue and exsitue techniques. Heavy rains for short duration creates runoff such water can be collected in a pond and used during the prolonged dry spells of *kharif* season and for *rabi* cultivation (Desai *et al.*, 2007). Various studies revealed that the water stored in a farm pond without lining evidence of seepage losses and also salinity, water logging etc., which ultimately decreases the fertility of the adjacent agriculture, lands (Getaneh, 2013; Samuel, 2013; Jayanthi, 2004).

Farm pond lining is a process of installing an impervious material in a pond to reduce the permeability of the soil from insignificant or to at least to tolerable limit. The size and depth of farm pond depends on various factors like soil type, available land, farmer's requirement, possible use of excavated land (Mane *et al.,* 2015; Goyal, 2009; Desai *et al.,* 2007) and probable runoff of the region (Ambati *et al.,* 2011). Table 1, 2 and 3 showing the infiltration rate and seepage loss through different types of soils respectively.

Lining materials

This article is a review on various types of lining material. Lining material is necessary where the infiltration rate of soil is more than 10mm (Srivastava, 2004). The paper presents easily adaptable various types of lining materials like clay, soil cement, concrete, chemicals like bentonite, Sodium bicarbonate, polymers like HDPE, LDPE, Silpoulin, LLDPE etc. and their major site specific annotations. In a study made by CRIDA, on evaluation of different lining materials at Bangalore, the total water loss per day was maximum with soil + cement (8:1) lining while the loss per unit volume was higher with stone powder + cement (8:1) lining (54.3 lt/m^3) followed by stone slab (45.5 lt/m^3) and the loss per unit volume is minimum in brick lining (20.1 lt/m^3) (ACRIPDA, 2014-15).

Effect of lining materials

Clay lining: Excessive seepage in alfisols and luvisols can be abridged through clay lining where as in vertisols soil compaction can reduce seepage losses. Impounding area should be compacted proportionately for two to three times and well graded material containing at least 20% clay can be applied evenly as liner studies conducted in various regions are shown in table 4. Clay lining is the cost effective compared to plastic membrane, biocrete and concrete lining (Jayanthi *et al.,* (2004). Thickness of the blanket varies from 10 to 30cm depending on the depth of water impounding and type of soil.

Soil cement

Is a highly compacted mixture of natural soil/ aggregate and portland cement, the soil material can be in any combination of sand, silt, clay and gravel which is readily available. Soil cement is a mixture of portland cement and natural soil. For best results the soil should be graded with a maximum size of $3/4^{th}$ inch and contains 10 to 35% fines passing the No. 200 sieve (Bureau of reclamation). Rate of application and ratio of soil cement shall be determined based on laboratory test and field situations. Depending on the depth of water stored, thickness of the lining material is fixed as 4" for water depth up to 8 feet and 6" for water depth up to 12 feet (NRCSCPS, 740-1).

Various studies shown in table 5 revealed that runoff water stored in farm pond used to irrigate kharif crop during dry spells and for rabi crop production (Islam *et al.,* 2017; Wallace and Bailey, 2015; Subudhi and Senapathi, 2013; Dhanapal *et al.,* 2010; Jayanthi *et al.,* 2004). On an average 93.5% seepage is reduced with 4.9 l/m^2/day. Though the seepage losses from the lined pond are increasing year after year it can be adapted where the budget is a constraint.

Polymer lining

Waterproof lining material for pond are polyethylene, vinyl, butyl rubber and asphalt sealed liners are widely accepted in a thin film form but if not broken or punctured. Thickness of plastic films ranges from 3-20 mils. Before lying a plastic film pond area should be cleared with gravel greater than 6 inch to protect it against puncture.

Table.1 Seepage losses and percolation losses in different soils

Type of soil	Water loss through seepage (cumec/million m^2 of wetted area)	Drop in depth per day (cm)
Heavy clay loam	1.21	10.36
Medium clay loam	1.96	16.84
Sandy clay loam	2.86	24.61
Sandy loam	5.12	44.03
Loose sandy soil	6.03	51.80
Porous gravelly soil	10.54	90.65

Source: Agritech.tnau.ac.in

Table.2 Infiltration rates of different types of soil

Soil Type	Infiltration rate (cm/hr)
Clay	0.5
Clay loam	0.8
Silty loam	1.0
Fine sandy loam	1.2
Fine sand	1.2-2.0
Coarse sand	2.0-2.5

Source: www.nabard.org

Table.3 Effectiveness of different lining material for seepage control

S. No	Lining Material	Seepage loss, l/hr/m^2
1	Control (No lining)	18.56
2	Cowdung + Paddy husk+Soil plaster (1:1:10)	16.98
3	Cementplaster at bottom (1:6)	12.99
4	Cement + Soil plaster (2:10)	0.85
5	Polythene sheet	0.32
6	Paddy husk +Ash plaster	11.6
7	Coastal saline soil plaster	5.47
8	Fly ash + Sand Plaster	2.5
9	Clay	12.07

Source: Panigrahi, B. 2011

Table.4 Study on clay lining

Location	Observations	Source
Tellapalem, Machlipatnam	Compared to Geosynthetic membrane, Prefabricated asphalt membrane, Polyethylene and concrete lining, clay carpet of 10cm found to be most effective in sealing the soil in sandy soils and cost effective.	Phanikumar *et al.*, (2013)
Ethiopia	Storage efficiency showed significant improvement where as water surface temperature has not shown any significant variation in luvisols, whereas on vertisols there is no significant improvement in seepage control.	Getanseh and Tsigae. (2013)
Orissa, India	Seepage reduced by 57 % compared to unlined pond	Jayanthi *et al.*, (2004)

Table.5 Study on Soil cement lining

Material	Location	Observations	Source
Biocrete	Bangladesh (delta plain)	Seepage losses reduced by 93.81% through Biocrete whereas clay and polyethylene lining showed reduction of 56.73% and 76.37% respectively.	Islam *et al.*, (2017) Wallace and Bailey (2015)
Soil Cement	AICRPDA, Orissa	Soil Cement lined (6:1) 8cm thick gave highest result in storing the water for reuse when compared to un-lined pond which could not retain water for rabi season.	Subudhi and Senapathi (2013); Subudhi and Sagra, 2010
Soil Cement (Small Pond) Kadapa Slab(Big Pond)	Alfisols in dry lands of Karnataka	8:1 proportion of soil and sand with 5cm thickness recorded minimum seepage of 4.9 l/m^2/day, compared to the seepage from brick and cement lining (Kadapa slab) of 137 l/m^2/day).	Dhanapal *et al.*, (2010)
Soil Cement(6:1)	DARP, OUAT, Pulbani, Orissa.	Three years (1998- 2001) of study recorded average seepage under four treatments i.e. unlined, (6:1) 6cm thick soil cement, 8 cm mortar lining and (8:4:1) concrete lining recorded as 936, 78, 12.26 and 39 l/day respectively.	Subudhi (2010)
Soil Cement (Biocrete)	AICRPDA, Phulbani, Orissa, India.	Sand and cement in 10:1 ratio with 5cm thick lining showed reduction in seepage to 93.81% compared to polyethylene, clay and chicken litter.	Jayanthi *et al.*, (2004)

Table.6 Effectiveness of silpaulin as lining

Material	Thickness	Location	Observations	Source
Silpaulin Nylon	200GSM 500 GSM	Himalayan region	More stable and longer life	Singh *et al.*, (2010)
Silpaulin	200GSM	Kasaragod (Dist.) Kerala.	Cost incurred for the lining material is less compared to concrete masonry, brick masonry, Ferro cement and fiber glass.	Samuel and Mathew *et al.*, (2008)
Silpaulin	250µ	North eastern region of India	Rain water was harvested and used for rabi cultivation.	Das *et al.*, (2017)
Silpaulin	500GSM	North east hilly region of India	Comparing with annual seepage of 255.15m^3/annum, lined canal showed 100% sealing.	Samuel *et al.*, (2013)

Table.7 Effectiveness of HDPE lining

Material	Location	Observations	Source
HDPE (GSM UV sheet Irradiated Plastic)	Erumapatti block Namakkal district, Tamil Nadu	Seepage losses are reduced considerably compared to unlined pond. Which resulted in growth in crop production as irrigation frequency is increased through plastic lined pond than unlined pond.	Mohan *et al.*, (2013)
HDPE (250µ)	Kerala and coastal Karnataka	Compared to soil cement mixture with 10% cement content HDPE liner proved to be equally effective and cheaper, when lined at the bottom and sides. Rate of percolation was 1.2cm/ 30days, where as soil cement noted 0.54 cm/hr.	Mathew *et al.*, (2008)
HDPE+ Concrete	Neeradevdhar project, India	Combination of concrete over HDPE sheet shown 100% seepage control compared to 70 % of seepage control by concrete lining.	Kadu *et al.*, (2017)

Table.8 Effectiveness of LDPE (250µ) lining

S. No	Location	Lining Method	Observations	Source
1	Meghalaya	A film of 250µ was covered with 30cm soil and stone pitching of sides as protection	Seepage losses are reduced from 55 l/m^2/ day to 2.9 l/m^2/day i.e. by 94.7%	Singh *et al.*, (2006)
2	North east region of India	Sheet was spread over clay lining of 3-5cm.	Seepage losses are completely arrested with decreasing rate of maintenance cost ranging from 0.14/l to 0.046/ l from 1st to 3rd year.	Saha *et al.*, (2007)
2	Northeast India	UV resistant lining (LDPE) is used	Seepage loses were reduced considerably	Manoj and Satapathy (2008)
3	Himachal Pradesh	30 cm of soil was covered over the agri film	Seepage loss reduced from 55 to 2.91 l/m^2/day i.e. by 94.7%	Singh *et al.*,(2010)
4	North east region of India	A film of 250µ was covered with 30cm soil	Seepage losses are reduced by 93% i.e. from 0.04m^3/m^2 unlined pond to 0.0029 m^3/m^2 lined	Rao *et al.*, (2010)

Table.9 Effectiveness of lining using different materials

S. No	Material	Location	Observations	Source
1	Sodium Bicarbonate	Islamabad, Pakistan	Compared to untreated soil physical and biological methods reduced the mean cumulative seepage by 72% and 67% respectively in arid areas. Both the methods are cost effective and easily adaptable.	Ahmad *et al.*, (1996)
2	Sodium Bentonite	CEWRE, Lahore, Pakistan	5% of mixing percentage of Sodium Bentonite with sand has showed 100% efficiency under lab condition and 92% to 96% efficiency under field condition.	Shehzad *et al.*, (2017)
3	LLDPE	Deschutes canal project, USA	0.75 mm sheet showed seepage reduction up to 99% by 98% by PVC film of same thickness	Stark *et al.*, (2009)
4	Geomembrane	IIT, Delhi.	0.6mm novel sheet developed by IIT, Delhi is UV resistant, thin, made to overcome the limitations of HDPE and PVC lining presently being used.	Deopura and Chahar (2010)
5	Concrete	Hyderabad	Evaluated that only brick lined pond with cement plaster could control seepage and withstood well for years whereas plastic, asphalt, soil cement etc. proved to be ineffective in the fourth year of lining.	Mishra *et al.*, (2009) Mishra *et al.*, (1994)
6	Clcarious soil lining	Bilwara, Rajasthan	Seepage rate reduced to 62% with 1.08 cm/m^2/day with 100% $CaCO_3$ lining and seepage rate increases with the decrease in the $CaCO_3$ lining percentage with 60cm and 30cm as 1.35 and 1.75 cm/m^2/day respectively.	Jat *et al.*, (2011)

Table.10 Economics for different types of lining material

Type of material	Cost/ Benifit	Source
Silpoulin	Rs.0.14/ l considering replacement after 5 years	Das *et al.*, (2017)
Table salt	125 $birr/m^{3,}$ compared to 522 bir/m^3 with soil cement lining	Getanesh and Tsigae (2013)
Calcarious soil lining	B:C ratio of 10cm lining showed 1.71:1	Jat *et al.*, (2011)
HDPE+Concrete	B:C ratio of lining showed 10.43:1	Kadu *et al.*, (2017)
HDPE	B:C ratio of lining showed 1.6:1 with payback period of 10 years	Mishra *et al.*, (2009)
Soil Cement	B:C ratio of lining showed 3.04:1	Subudhi and Senapathi (2013)

Silpaulin is durable, light weight and water proof material. Plastic lining has great acceptance for seepage control. These sheets are made up of waterproof UV-stabilized, heat-seated, multi-layered and cross-laminated plastic materials and hence ensure high tensile strength, long life and high resistance to external pressure. Generally, trapezoidal-shaped storage tanks are constructed by excavating soil and dumping the removed soil along the four sides of the tank. Silpaulin of 200 and 500GSM is mostly used and found effective. Table 6 shows the lining results by various researchers in different parts of India.

High Density Polyethylene Tarpaulins made out of Industrial strength HDPE Woven fabric and re-inforced with lamination of LDPE on both sides. In comparison to concrete and shortcrete, HDPE and LDPE lining is cost effective as it does not require any maintenance except that it should be protected from mechanical damage by maintaining water continuously. Studies shown in table 7 reported that 1.2 cm/month seepage, and almost 100% seepage control in case of undamaged sheet. Where as in case of LDPE sheet (Table 8) seepage loss reduced from 55 to 2.91 l/m^2/day showing percentage of reduction ranging from 93% - 95% (Rao, 2010; Singh, 2010; Singh, 2006).

Bentonite is natural clay which has the characteristic of swelling 10-12 times its dry size. It showed 92% to 96 % of efficiency in seepage control for best results, application should be done at the depth of 25-30cm. Cost incurred in this method is high due to the cost of bentonite and the field preparation (Shehzad *et al.,* 2017). Other Lining materials like Sodium Bicarbonate, LLDPE, Geomembrane, Concrete and Calcarious soil lining were studied by various researchers shown in table 9. Riaz and sen (2005), has taken up a project with Geobembrane lining with soil cover to control seepage, water logging and salinity and reported that it is durable for two years. Harvested water can be used for life saving irrigation furthermore to get maximum benefits diversified farming like aquaphonics, agri-horti- selvi pastoral system can be adopted (Das, 2017; Samule, 2013). A study revealed the benefit cost ratio of HDPE is the best also with maximum seepage reduction along with B: C ratio of 10.43, compared to IITD + Shortcrete, Geotextile cover + shortcrete, Geotextile cover + concrete and IITD + concrete showed the B: C ratio 9.59, 6.83, 5.4, 6.95, 6.83 respectively (Kadu *et al.,* 2017). Therefore considering the geological conditions HDPE lining if effective as lining material in polymers (Mohan *et al.,* 2013; Mathew *et al.,* 2008). Cost involved in silpouline lining ranged from Rs.0.14per liter to Rs.0.71per liter (Das *et al.,* 2017; Samule, 2013) (Table 10).

Extensive review concludes that field experiments at various regions using different combinations of lining materials shows that polymer based lining has good effect on seepage control. Provided, depending on the type of soil, lining material can be selected. Where the durability is matter of concern like canal lining or big farm ponds planning to conserve water to cover large areas than HDPE in combination with concrete showed 100% seepage control as the concrete alone has not proved to be efficient due to thermal expansion and contractions. Bentonite, though costly has shown significant results by reducing the seepage losses by 72% to96% respectively, depending on the thickness of application. Clay lining and soil compaction is the cheapest lining method provided the ponds should be erected in vertisols. In case of alfisols, luvisols of arid and semi-arid regions require lining materials with diversified crops and conservative irrigation practice to get maximum benefits and

minimum payback period. Benefit cost ratio for HDPE lining in combination with concrete showed highest value of 10.4:1.

Recommendations

Some advanced techniques like Bentonite, polymer spray and geo-membrane in combination with protector cover can be undertaken for studies. Region specific recommendations are to be developed to adopt by the farmers individually or as a community or group. Government is encouraging the water harvesting structures in few parts of the country by providing subsidies for the cost of construction. In addition to this, farm ponds along with the suitable lining material can be provided for agriculture lands by providing subsidy. Advanced techniques and technicians like polymer spray and sprayers are to made available in local markets.

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