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HYDROLOGY AND WATER QUALITY OF TRADITIONAL RAINWATER HARVESTING DRINKING WATER POND AT SAMUTHIRAPATTY VILLAGE, DINDIGUL DISTRICT, TAMIL NADU

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ABSTRACT

Shortage of water is a cause of concern throughout the world especially in developing and under-developed countries. India has already become water stressed country. Rainwater harvesting has been in practice around the world since ancient days. Traditional rainwater harvesting structures present exhibit the existence of such practice in India. Rainwater harvesting ponds, called as '*Oorany*' in Tamil language, are prevalent and are being used for drinking purpose in part of Dindigul District, Tamil Nadu State, India. Samuthirapatty is a rural village in Natham block, Dindigul district has one such pond, which was established three century back. An attempt has been made to study the hydrological and physico-chemical parameters of Samuthirapatty pond. The capacity of the pond is 23.53 million litres. Runoff potential estimation indicates that the rainfall excess works to 321.48 million litres over one square kilometre of area for the 50-year mean monthly rainfall. The present annual drinking water demand of Samuthirapatty is 23.50 million litres. Pond water is very soft with the total dissolved salts of 58 mg/L. Excess iron, turbidity and fecal coliform render the water unsafe for drinking. Pond water enjoys palatability and is the preferred choice for drinking and cooking. Promotion of point-of-use (POU) water treatment system with community education may render the system sustainable. These type of ponds may be rejuvenated and will be very helpful to ensure water security as supplementary sources.

Keywords: drinking water pond, oorany, rainwater harvesting, traditional water ponds.

INTRODUCTION

Environment of the earth is unique in nature. Presence of water (hydrosphere) on the crust of earth planet keeps the earth as the only live planet in the solar system Rainwater, surface water (river, lake, pond and reservoir), groundwater and sea water are generally considered as the sources of water for the various demands. In the earlier phase of human civilization, the dispersion of human settlement was along the river courses. Rain is the primary source of water and others are derived from the same. In the absence of present technologies like: hard rock drilling, mud rotary drilling, open well excavation, etc, people had been adopting rainwater harvesting technique through artificial pond for the domestic purpose. Such systems are known as traditional structures/methods. Roof-water collection and rainwater harvesting in artificially dug ponds (called *Oorany* in Tamil) have been in practice in the eastern parts of Sivagangai District, Tamil Nadu State. Most of the rural habitations have at least one such a traditional rainwater-harvesting pond for drinking purpose. These had been the sole source of water supply till 1960's (Mariappan, *et al*, 1999a, 1999b, 2000, 2005). People of this region also prefer pond water for drinking purpose than the groundwater owing to its softness and accustomed taste (Mariappan, *et al*, 1998).

Nowadays, increase in water demand for various uses has rendered the management of drinking water resources more complicated. Water use is varying with time and place besides many fold increase in demand. Proper management of water quality in the traditional ponds may help in ensuring water security. The present paper details the quality of pond water with the hydrological characteristics of a traditional rainwater harvesting pond located at Samuthirapatty village.

Pond system

Drinking water ponds are found in the coastal Districts like Pudukottai, Sivagangai, Ramanthapuram, Virudhunagar, Thoothukudi and part of Dindigul districts in Tamil Nadu State. Presence of similar structures has been reported in Orissa State (Naik, and Purohit, 1996) and other coastal areas of India. It is ascertained that some of these ponds were created by the Kings, other rulers, rich individuals, and saints. In Sivagangai District of Tamil Nadu State, it is peculiar to note that some such infrastructures were created as a part of rituals by the inhabitants. For example, one of the ponds was constructed as owed at a temple for getting a male-child. These ponds are fed by well-connected inflow channel system, and a separate link channel from the irrigation tank has been made to feed the pond in a few places. Some of the ponds have masonry retaining walls. No relationship is observed between size of pond and habitation. In some locations, the ponds are being well protected by placing notice boards inscribing like "Drinking water pond; do not pollute; do not enter with chapels".

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Description of study area

Samuthirapatty is a rural village in Natham block of Dindigul District. It is located ($10^0$12'59"N and $78^0$17'25'"E) on the Natham -Karaikudi highway at about 9 km from Natham (Figure-1). Village type settlement with heterogeneous community is seen. Present population is 1632 as per census 2011. Topography is hilly area with a valley in between. Rain fed agriculture is in practice and small grains are cultivated. Land treatment is mostly contoured and terraced with good hydrologic condition. The hydrologic soil group prevailing is moderately low runoff potential (Soil group B). A piped water supply system with groundwater as source besides a few hand pumps serves the habitation.

Figure-1. Location map.

Climate prevailing is arid to semi arid. Rainfall is occasional and is received by South-West monsoon in (June to September) and North-East monsoon (October to December). Major portion of the precipitation occurs during October and November. The annual average rainfall is 836 mm. The mean monthly rainfall estimated based on 50 years of data is depicted in Figure-2.

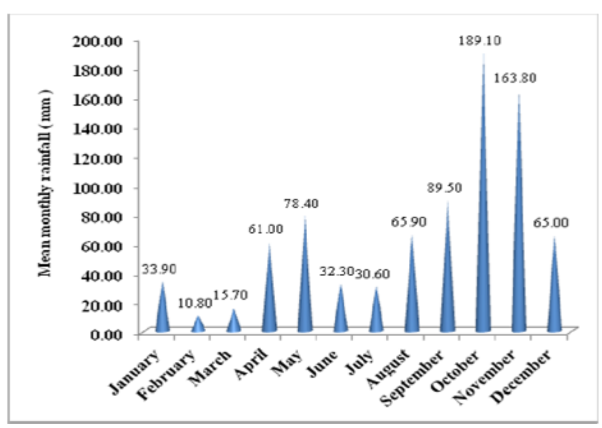

Figure-2. Mean monthly rainfall.

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A traditional rainwater harvesting pond, told to be constructed 300 years ago, with retaining wall is present and still is being utilised (Figure-3) for drinking purpose.

Figure-3. Traditional rainwater harvesting pond at Samuthirapatty.

Figure-4. People fetching water from the pond.

Figure-5. Bird's eye view of the Pond at Samuthirapatty.

Figure-4 shows the ladies taking water from the pond. The aerial view of the pond is depicted in Figure-5. The pond has telescopic cross section with 4 levels of cross section. The cross section sizes of the pond at different levels are: (94 m × 89 m) with a depth of 2.70 m, (54 m × 67 m) with a depth of 0.55 m, (28 m × 34 m) with a depth of 1.30 m and the inner most part has the size of (22.45 m × 16.70 m) with a depth of 2.50 m. As shown in Figures 3 and 4, it has retaining wall all around at outer and inner sections with an inlet. It was ascertained that the pond belongs an individual (private property) from Siruvayal near Karaikudi.

MATERIAL AND METHOD

Runoff estimation

Runoff is one of the most important variables used in the planning of water resources management including water quality management. Several methods to compute runoff from a rainfall event have been developed since the first widely used rainfall-runoff model proposed by the Irish engineer Thomas James Mulvaney in 1851. One of the popular methods for predicting the surface runoff volume from a rainstorm from small watershed is the Soil Conservation Curve Number (SCS-CN) methodology which was developed by the Soil Conservation Service (now called the Natural Resources Conservation Service,, NRCS) of the United State's Department of Agriculture (USDA) in 1954 (Mariappan,1990). The SCS-CN method converts rainfall into surface runoff using its parameter Curve Number (CN) which represents the runoff potential of a watershed characterized hydrologic soil type, land use pattern and treatment, ground surface condition and antecedent moisture condition (AMC).

The SCS-CN method consists of the following equations:

$$P = Ia + F + Q \qquad (1)$$

$$\frac{Q}{(P - Ia)} = \frac{F}{S} \qquad (2)$$

$$Ia = \lambda \times S \qquad (3)$$

Where P= total rainfall, Ia=initial abstraction, F= cumulative infiltration excluding Ia, S=potential maximum retention or infiltration.

Equation (1) and (2) lead to the popular form of the SCS-CN method given below.

$$Q = \frac{(P - Ia)^2}{(P - Ia + S)} \qquad (4)$$

Equation (4) is valid when P ≤ Ia: Q = 0 otherwise. Ia= 0.2S, and becomes

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad (5)$$

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Louis Berger International Inc., and Water Power Consultancy Services (India) Ltd. Found the following equations better suited than equation(5) for Indian conditions. According to them, for all regions including black cotton soil areas with AMC I

$$Ia = 0.3S \tag{6}$$

And for regions with black soils with AMC II and AMC III, it is given by

$$Ia = 0.1S \tag{7}$$

Substituting, Equation (7) in equation (4), yields

$$Q = \frac{(P - 0.1S)^2}{(P + 0.9S)} \tag{8}$$

The empirical studies conducted by SCS further indicated that S can be estimated by

$$S = \frac{25400}{CN} - 254 \tag{9}$$

Runoff per unit area (square metre and square kilometre) is determined to assess the inflow into the pond. The water demand for the entire population of the village assuming a requirement of 10 litres per person per day (LPCD) and 40 LPCD are estimated.

Water quality analysis

Water sample from the pond and bore well were collected in two litres capacity for physico-chemical analysis and bacteriological test. As the water-depth in the pond was shallow, mixed sample of two litre was collected by taking water at surface and at bottom. Samples for bacteriological analysis were collected in sterilized bottles. Physico-chemical and bacteriological parameters were analyzed as per standard methods (APHA, 1989) in the district level water testing laboratory of TWAD Board located at Dindigul city.

Water quality index

The water quality index is a rating of water quality parameters by a single numerical expression reflecting the composite influence of water quality parameters (physical, chemical and bacteriological) significant for a specific beneficial use. It is a useful tool for ascertaining the overall water quality of water resources. The quality ratings and weights of various water quality parameters such as dissolved oxygen, pH, coliform count/density, specific conductance, alkalinity, chloride and carbon chloroform extract were considered to reckon the water quality index through an arithmetic weighted mean method. Even though as many as parameters were studied, 10 parameters were taken for calculating water quality index (Horton, 1970; Deininger and Maciunas, 1971; Harkins, 1974; Tiwari and Manzoor Ali, 1988; Diwedi *et al*, 1997). Parameters, DO, BOD, coliforms, chloride, turbidity, total solids, pH, toxic metals and temperature were considered to reckon WQI. In another study, pH, conductance, DC, total harness, chloride, Sulphate, calcium, magnesium and total solids were to determine WQI. In the present study, the following 10 parameters are considered to calculate WQI for drinking purpose with CPHEEO (1999) standards: pH, Turbidity, total dissolved solids, total hardness, chloride, calicum, sulphate, magnesium, nitrate and electrical conductivity. The formation of a water quality index is closely related to the intended use of water. The unit weight factors for chosen parameters are given in Table-1. It is well known that the more harmful a given parameter is the small is its permissible value for drinking purpose. So, the weights for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters. Unit weight factors, Wi, is given by the formula:

$$W_i = \frac{K}{S_i} \tag{10}$$

where S_i is the standard value of ith parameter and *K* is a proportionality constant. The quality rating q_i' for the ith parameter except pH is given by

$$q_i = 100\frac{Vi}{S_i} \tag{11}$$

For pH, $$q_i = 100\frac{(VpH - 7.0)}{(9.20 - 7.0)} \tag{12}$$

Where Vi and VpH are the observed water quality parameters. The water quality index (WQI) can be calculated employing the relationship:

$$WQI = \frac{\sum_{i=1}^{10} q_i w_i}{\sum_{i=1}^{10} w_i} \tag{13}$$

According to the condition of unit weight factor, the value of $\sum_{i=1}^{10} w_i$ is 1. Thus, equation (13) becomes

$$WQI = \sum_{i=1}^{10} q_i w_i \tag{14}$$

Table-1. Unit weight factors for Water Quality Index (WQI).

S. No.	Parameter	Unit weight (Wi)
1.	pH	0.0027
2.	Turbidity	0.4000
3.	Total dissolved solids	0.4276
4.	Total hardness	0.0067
5.	Chloride	0.0040
6.	Calcium	0.0200
7.	Sulphate	0.0100
8.	Magnesium	0.0270
9.	Nitrate	0.0890
10.	Electrical conductivity	0.0130
	Total	1.0000

RESULTS AND DISCUSSIONS

Runoff estimation

The runoff potential estimated using SCS curve number technique and the village demand for drinking purpose is presented in Table-2. It is observed that the annual runoff potential is about 321 million litres taking the catchment area as 1 km^2. The drinking water demand at 40 LPCD (CPHEEO, 1999) for present population is estimated at 23.50 million litres, which is well below the runoff potential. The capacity of the pond is 23.53 million litres. It suggests that the entire drinking water demand can be met from the rainwater collection (runoff) just slightly increasing the catchment area in order to balance the evaporation and other losses. Present drainage channel may be improved and extended with a few silt trap arrangements to collect the runoff effectively. Mass balancing the supply and demand encourages the rainwater harvesting in the pond for sustainable water management.

Table-2. Runoff potential with demand.

Month	Rainfall (mm)	Runoff depth (mm)	Runoff per km^2 (million litres)	Demand at 10 lpcd (million litres)	Demand at 40 lpcd (million litres)
January	33.90	4.01	4.01	0.49	1.96
February	10.80	0.00	0.00	0.49	1.96
March	15.70	0.20	0.20	0.49	1.96
April	61.00	15.78	15.78	0.49	1.96
May	78.40	25.81	25.81	0.49	1.96
June	32.30	3.51	3.51	0.49	1.96
July	30.60	3.02	3.02	0.49	1.96
August	65.90	18.45	18.45	0.49	1.96
September	89.50	32.93	32.93	0.49	1.96
October	189.10	110.57	110.57	0.49	1.96
November	163.80	89.26	89.26	0.49	1.96
December	65.00	17.94	17.94	0.49	1.96
Total	836.00	321.48	321.48	5.88	23.50

Water quality

The physico-chemical and bacteriological quality of pond and bore-well waters are tabulated with the drinking water standard for comparison (Table-3). It is observed that the Total Dissolved Salts (TDS) is just 58 mg/L in the pond water against 1205 mg/L in the bore-well water. The desirable level of TDS for drinking purpose is less than 500 mg/L (BIS 10500, 2000). In addition to the potability, palatability decides the acceptability. Potable water lacking palatability is sometimes not preferred by the people. At Samuthirapatty, people prefer pond water for drinking and cooking because of its taste. Hard water is generally not chosen, especially for cooking. Pond water is more turbid than the bore well water. Natural settling is found to be in sufficient and colloidal particles require destabilizing process. A comparison of TDS, Iron and fecal coliform estimates between the pond water and the bore-well water is shown in the Figures 4 to 6. Iron content in the pond water is higher than the groundwater. Pond has been constructed using laterite stone. Geological formation may be having iron-bearing minerals and is carried by the runoff. Improper sanitation system in the village may be causing bacteriological pollution. Water needs disinfection.

Table-3. Water quality with drinking water standard.

S. No.	Parameter	Pond water	Bore-well water	Drinking water standard, IS 10500	
				Desirable	Cause for rejection
1	Appearance	Turbid	Clear	…	…
2	Colour (pt.co-scale)	Brownish	Colourless	5	25
3	Odour	None	None	unobjectionable	
4	Turbidity NT units	25	7	5	10
5	Total dissolved solids	58	1205	500	2000
6	Electrical conductivity micS/cm	85	1771		…
7	pH	6.40	7.82	6.5-8.5	6.5-8.5
8	Alkalinity total as $CaCO_3$	2	312	200	600
9	Total hardness as $CaCO_3$	20	360	200	600
10	Calcium as Ca	6	77	75	200
11	Magnesium as Mg	1	40	30	100
12	Sodium as Na	8	196	200	200
13	Potassium as K	3	50		
14	Iron total as Fe	0.79	0.56	0.3	0.3
15	Manganese Mn	0.00	0.00	0.1	0.3
16	Free Ammonia as NH_3	1.48	0.38	0.5	1.0
17	Nitrite as NO_2	0.27	0.37	0.5	1.0
18	Nitrate as NO_3	3	9	45	45
19	Chloride as Cl	16	334	250	1000
20	Fluoride as F	0.3	0.4	1.0	1.5
21	Sulphate as SO_4	13	63	200	400
22	Phosphate as PO_4	0.55	0.81	0.5	1.0
23	Faecal coliform, numbers/100ml	11000	0	0	0

The critical parameters, which render water not potable for drinking, in the pond water are turbidity, iron and fecal coliform. It is certain that the surface runoff has higher turbidity than the groundwater. Similar pattern of quality has been reported in community ponds in Rourkela by Naik and Purohit (1996), and in Sivagangai district, Tamil Nadu (Mariappan, *et al*, 1999b). As such, pond water solicits some kind of treatment to make it safe for drinking.

Water quality index

The water quality index (WQI) of pond water and bore well water is shown in Figure-7. WQI of pond water is 37 where as the groundwater records 549. More is the WQI; more will be the salts and inferior in palatability.

Quality management

The people of the study area traditionally use *Strychnous potatorum* (*Thethankottai* in Tamil) seed at household level to clarify the turbid pond water. In each of the houses, at least 1 to 2 kg of above seeds are kept as stock. It is sold at about Rs 30 to 40 per kg in the markets. The procedure adopted is very simple: pond water is collected in mud pots and a seed (nut) is slowly rubbed with gentle pressure by hand on the inside wall of the pot. On rubbing the seed, the roughness of pot surface facilitates formation of floc. As a result, white gelatinous product is generated and settling takes place. This exercise is to be continuously done for 5 to 15 minutes depending upon the initial turbidity. Finally, the supernatant is drawn for use. The seed, *Strychnos potatorum,* contains an organic compound called strychnine and albumin. Literatures reveal that the albumin is responsible for clarification process.

Recently, the concept of soliciting community participation in planning, design, execution and operation and maintenance of water supply schemes is being promulgated in India. But, people of Sivagangai district had such practice in the past. Moreover, they had their own method of clarifying pond water for quality management. Children learn this technique from their parents. Neither a Public Health Engineer nor the Government organises training programme. Entire aspects are looked after by themselves.

Another quality problem with the pond waters is excessive iron. It is observed from the results that oxidation of ferrous salts perhaps lead to reddish coloration and turbidity. In Sivagangai district, it has been reported that ponds having lotus plants show less iron presence (Mariappan, *et al*, 1999b). It implies that the lotus plants may absorb iron from the water and perhaps render clear water. Further advantage is that the leaves of lotus cover the surface and reduce the surface waves generated by wind. Hence, a favorable environment for settling is created. An added advantage of having lotus plants is minimization of evaporation loss.

Pond sand filter was recommended by Ahmed and Sikder (1997) for clarifying pond waters in saline coastal areas. Such a system may also invite little attention for proper upkeep. Most of the technical interventions fail in water quality management because of mismatch between the user choice and new methodology.

To purge bacterial population, demarcation of catchment area to restrict the open-air defecation, improving sanitary condition of habitation and placing notice boards may be encouraged. In addition, super chlorination of pond water after every fresh shower may help a lot. Natural purification also favors. Further, people may be encouraged to boil the water properly at household level.

CONCLUSIONS

Traditional rainwater harvesting drinking water pond located at Samuthirapatty in Dindigul district exhibits the method of water supply system done in the earlier days. It stands as an example sustainable user preferred system till today even after 300 years after construction. With masonry structure, its water holding capacity is 23.53 million litres. Mean monthly rainfall indicates the runoff potential per km^2 as 321.48 million litres. The annual drinking water demand of Samuthirapatty village for the 1632 population can be met from the rainwater collection in the pond as an eco-friendly method (without causing carbon emission). . Pond water is generally soft and preferred by the users. TDS of pond water is just 58 mg/L, which is similar to the packaged drinking water being sold in the market at Rs15 per litre. WQI shows better quality of pond water to the alternative groundwater source. Little intervention is required to bring the quality within stipulated standards. Promotion of point-of-use (POU) water treatment system with community education may render the system sustainable. This type of ponds may be rejuvenated and will be very helpful to ensure water security as supplementary sources.

REFERENCES

Mariappan P. *et al*. 1998. Acceptance of drinking water quality standards by a community - A case study. Journal of IPHE(India). (2): 1-4.

Mariappan P. *et al*. 1999a. Correlation coefficients of some physico-chemical parameters of drinking water ponds in eastern part of Sivagangai district. Pollution Research. 21(4): 451-456.

Mariappan P. *et al*. 1999b. Water Quality in drinking water ponds (Oorany) in eastern part of Sivagangai district, Tamil Nadu. Journal of Indian Water Works Association. XXXI(2): 125-129.

Mariappan P, *et al*. 2000. Traditional rainwater harvesting practices for drinking purpose in part of Sivagangai district, Tamil Nadu, 32nd Annual Convention of IWWA, April 22-24, Bhopal, Proceedings. pp. 45-52.

Mariappan P and M.Elango. 2005. Traditional rainwater harvesting and water quality management practices in Sivagangai district, State level workshop on Traditional rainwater harvesting systems in Tamil Nadu, Coimbatore, Proceedings. pp. 8-13.

Mariappan P. 1990. Estimation of Infiltration in changing land use pattern using SCS Curve Number Technique, M.E Thesis, Anna University, Chennai.

1989. APHA. Standards Methods for the examination of water and wastewater, Washington, DC.

Naik S. and Purohit K.M. 1996. Physico-chemical analysis of community ponds in Rourkela. Indian Journal of Environmental Protection. 16(9): 679-684.

Ahmed F. and Sikder M.E. 1997. Performance of Pond Sand filter in saline problem area, Journal of IPHE (India). (1): 10-16.

Horton R.K. 1970. An Index Number System for Rating Water Quality. Journal of Water Pollution Control Federation. 37(3): 300-306.

Deininger R.A. and J.J. Maciunas. 1971. A water quality index for public water supplies. Dept. of Environmental and Industrial Health, School of Public Health, University of Michigam, Ann. Arober, Michigan.

Harkins R.D. 1974. An objective water quality index', Journal of Water Pollution Control Federation. (3): 589-591.

Tiwari T.N. and Manzoor Ali. 1988. Water quality index for Indian rivers. Ed. R.K.Trivedi, Ashisa Publishing House, New Delhi. pp. 274-288.

Diwedi S., Tiwani I.C. and Bhargava D.S. 1997. Water quality of the river Ganga at Varanasi. Journal of the Institution of Engineers (India). 78: 1-4.

CPHEEO. 1991. Manual on water supply and treatment, Ministry of Urban Development, New Delhi, India.

Bureau of Indian Standard 10500. 2000. Drinking water standard, Government of India, New Delhi, India.