Manual for Rain Water Harvesting Pond on Municipal Solid Waste Sites

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Funded by MMR Environment Improvement Society, Mumbai

Ponds are often used for private as well as public recreation

Birds use ponds as breeding, feeding, watering places, and as resting places during migration

Contents

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Dr. Pramod Salaskar

Preface

This manual describes the requirements and provides guidelines for the construction of Rain Water Harvesting Pond with SV Trans treatment system on closed Municipal Solid Waste landfill site. This manual will be useful to the Municipal Corporations a guideline & reference for the engineer, technician and contractor**.** Rain Water Harvesting Pond can be used as a good alternative source for Municipal water supply for gardening & dowsing of fires if proper procedures are adopted for treatment & collection.

Creating Rain Water Harvesting ponds on the closed Municipal Dumping Grounds and using the same for afforestation or even for dousing the accidental fires which keep erupting every now and then and which pollutes the surrounding air due to burning of garbage.

All the municipal areas in the MMR are facing similar problems of proper management of solid waste landfill and the hazards associated with solid waste disposal sites. The pond based on MNP concept can be an effective solution for the water supply required for fire dousing operation.

Tree plantation can effectively mitigate the dust and gases emission from the landfill sites

Dr. Pramod Salaskar

1. Introduction

Management of solid waste dumping sites is a major problem faced by large Municipal Corporations. Foul smells, fire hazards, toxic leachate, and environmental pollution are some important issues associated with the dumping sites. Maharashtra Nature Park Society constructed a rain water harvesting pond (RWH Pond) on garbage dump /landfill site at Dharvai, Mumbai in the year 2003 and conducted a systematic plantation around it.

It was decided to evaluate its feasibility by assessing the quality of harvested water for which it has found to be most valuable /easily available resource to develop the ecosystem (both terrestrial and aquatic) on dumping site. During present study, the rain water harvesting pond in Maharashtra Nature Park was also assessed for "Ecological Quality Index (EQI)". The results were encouraging and indicated usefulness of such ponds. The water spread area of the RWH Pond of MNP is about 4184.07 Sq.m. and the total area of the Municipal Solid Waste disposal site is about 37 Acres. In the late 1970's, it was decided by MMRDA to restore the dumping site ecologically.

From 2010, Sunita Enviro and Maharashtra Nature Park Society (MNPS) started monitoring the water quality of RWH pond along with EQI and the results indicate that the Rain Water Harvesting Pond is compatible and qualified for the irrigation criteria as per CPCB guideline. It has proved to be an excellent example for the Ecological restoration of the unscientifically managed. Municipal Solid Waste Disposal sites

Generally the Municipal Solid Waste constitutes of high content of Organic matter, which by heat generation during the decomposition process makes MSW disposal sites vulnerable for fire hazards. Initially the water harvested in RWH

Pond at Maharashtra Nature Park was used to douse the frequent fire that took place at Landfill area, now a days it is being mainly utilized for the gardening purpose.

1.1 History of the Project:

MNP constructed RWH pond on MSW disposal site of Dharavi in the year 2003 for dousing on fire oftenly occurred at disposal site. The pond water was also utilized to irrigate the vegetation around MSW disposal site. In the year 2009MNPS approached MMREIS to conduct study on water quality of RWH pond to assess more probable uses of RWH pond, which was created as a part of RWH project and its ecological significance to the environment and society through developed ecosystem (terrestrial and aquatic)by evaluating EQI and to check the feasibility of project to propose findings of this study at other MSW under the MMRDA.

1.2 Objectives of the Project:

a) To assess the quality of the stored water in terms of physical, chemical and biological characteristics, its variations across the year i.e. during monsoon, winter and summer.

b) To study impact of any possible leachate (as the site is located on the erstwhile municipal landfill site) and its effect on water quality of RWH pond.

c) To assess the possibility of creating such ponds to conserve water which can be used for possible irrigation/gardening or making it available for dousing the frequent fires, taking place on the landfill site.

d) To study the effect of creating water bodies like this on the microbial stature in the subsoil areas around the water body.

e) To study beneficial or harmful nature of such experiments if replicated elsewhere.

f) Preparing manual for creating RWH Ponds in future elsewhere within MMR region.

2. Significance of Assessment of RWH Pond Water

The regular water quality monitoring and evaluation of all water resources have become a need of today, to maintain the healthy balance of the ecosystem for sustainable development. The various impurities present in water are expressed through various parameters called the water quality parameters (variables). The water quality variables are broadly classified into three categories, Physical, Chemical and Biological. The details are given as below:

Physical Variables: Colour, Odour, Water level, Temperature, Turbidity, Transparency, Suspended solids.

Chemical Variables: BOD, COD, Dissolved Solids, Dissolved Oxygen, Free Carbon dioxide, pH, Alkalinity, Acidity, Total Hardness, Nitrogen, Chlorides, Salinity, Calcium, Magnesium, Sulphate, Silica, Sodium, Potassium, Lead, Oil & Grease.

Biological Variables: Phytoplankton, Zooplankton, Benthos, Organisms & Microbes.

Water parameter studies are significant in assessment of aquatic ecosystems. They can illustrate the metabolic processes taking place in water and also indicate pollution status of the ecosystem. The only drawback of these studies is, they can indicate about the status only during the study being conducted. However, when parameters are studied at timely frequency and compared, it can indicate the long term changes in the ecosystem.

Ecological health of the lake or pond which describes the quality of water can be identified by measuring Dissolved Oxygen levels, Dissolved Solids, Turbidity, Nutrients (Nitrates and Phosphates), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Heavy Metals etc. Lake water quality should conform to the standards prescribed by the CPCB for its various uses; alternatively the management of the lakes or ponds should be focused on maintaining the ecological health of the water body.

3. Development of RWH Pond at MSW Site

Development of RWH pond at MSW landfill /old dumping site consists of collection of surrounding catchment water storage and reuse for ecological development on top of such waste disposal site instead of creating leachate and surface water pollution. Landfill RWH can also be used for recharge of ground water through percolation pits, open wells or bore wells. RWH pond is applicable only for trench landfill sites closed at ground level.

3.1 Size of the RWH Pond

The depth and water spread area of the pond should be dependent on area of landfill site. The following criterion shall be considered for the estimation of RWH Pond Size at MSW management site:

a. The height of the RWH Pond shall be 30% of the total height of the MSW.

b. The top surface of pond shall be minimum 30% of the total available surface area. It can be increased as per in-situ conditions.

c. Slope shall be maintained on the bank of the pond between 3:1 for safety purposes.

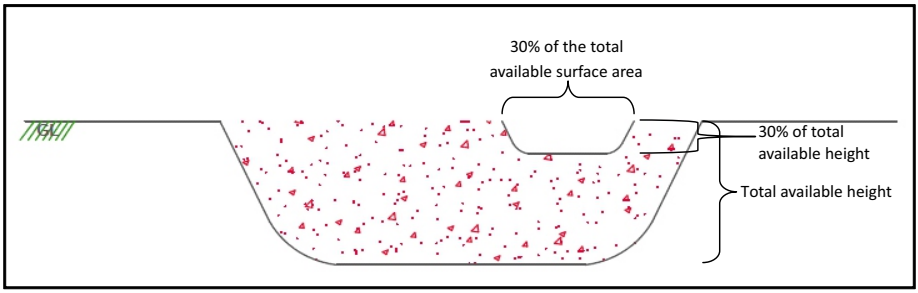


Fig. 1: Schematic representation of Surface area of RWH pond

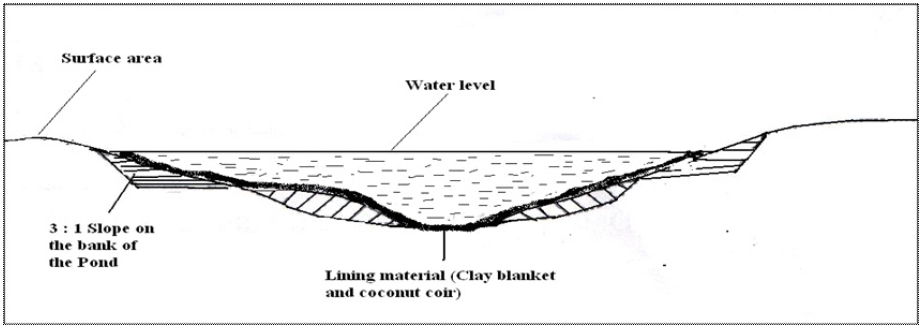


Fig. 2: Schematic representation of the proposed RWH Pond shape with required slope and lining material

3.2 Total water quantity

Estimating the volume: The volume of water can be estimated using the **Prismoidal** formula:

$$V = \frac{(A + 4B + C)}{6} \; X \; D$$

Where,

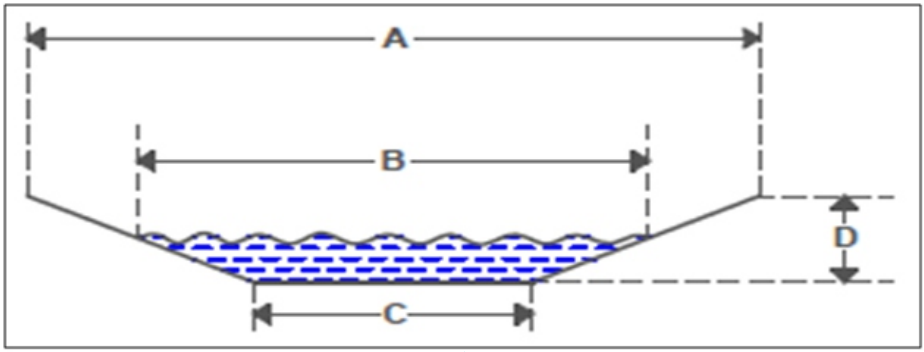
V = Total volume of water (m^3)

A = area of the excavation at the ground surface (m^2)

B = area of the excavation at the mid-depth (1/2 D) point (m^2)

C = area of the excavation at the bottom of the pond (m^2)

D = depth of the pond (meter)



3.3 Treatment to the Site

Leveling and compaction of the site shall be performed in order to get the uniform surface before constructing the RWH Pond. The excavation shall be done at a suitable place in the Landfill site where there is adequate depth. The surface slope shall be maintained in such way so that the surface run off gets collected into the RWH Pond.

The slope of the surface shall be covered with a layer of clay in order to give it uniform shape and to provide a strong base for the RWH pond as shown in figure number 02.

Lining material

- Entire waste will be covered by minimum 0.3 m clay mixed with bentonite powder. Bentonite percentage will be decided after lab test to achieve permeability of 1×10^{-7} cm/sec.
- Compacted bentonite mixed clay layer will be followed by 1.5 mm thick HDPE (High Density Poly Ethylene) sheet with hot wedge welding, according to MSW Rule 2000.
- Lines are properly anchored along the peripheral bunds of closure in anchoring trench. Entire waste shall be scientifically capped.
- Provide 0.6 m thick soil at bottom of RWH Pond.

Herbs and grasses should be planted during or soon after construction of RWH Pond. Their functions include erosion control, screening of pollutants from the surrounding catchment area, micro climatic effect control, and enhancing the biodiversity. The vegetation should be able to survive under the prevailing conditions with minimum maintenance.

Plants used for treatment of water in the RWH Pond have been mentioned below.

Sr. No.	Scientific name	Habitats	Common name
1	*Canna indica*	Herb	Canna lily / Indian shot
2	*Colocasia esculenta*	Herb	Wild taro, Elephant
3	*Vetivera species*	Grass	Vala
4	*Brassica juncea*	Herb	Mustard
5	*Helianthus annus*	Herb	Sunflower

The shoreline of RWH Pond (MNPS, Mumbai)

3.4 Natural treatment to the water

Natural treatment systems should be adopted in the immediate surrounding catchment area of the RWH Pond. Herbs and grasses should be planted in an organized manner across the Municipal Solid Waste site. The runoff water coming to the RWH Pond during monsoon season should be controlled by providing natural filtration system specially governed by Vetivera (SVTrans Treatment System).

3.5 Precaution and maintenance:

The above given system plays very significant role for maintaining the RWH Pond ecosystem intact. It can be very easily implemented at site and requires minimal maintenance during operation period. It requires minimum space for the implementation at site.

It will also reduce the pollution load dredging towards RWH Pond along with runoff water. It is very vital to implement at any solid waste management site and maintains healthy ecological conditions.

i. Precaution during storage:

- Aquatic Weeds should be removed from the RWH Pond to by providing aerators in RWH pond.
- The number of sprinkling units / aerators should be based on Dissolved Oxygen level and surface area of the Pond. Minimum required DO is ≥ 3.0 mg/lit.

ii. Access to Human Beings and Animals

Cattle can damage the artificially created ponds and should not have access to the pond. Cattle can damage ponds by trampling edges, exposing soil of pond banks through overgrazing, and muddying the pond through wading. Ponds or any water body attracts people so that there is always a chance of injury or drowning. The access to the animals and human being shall be restricted by providing fence or cow catcher system along the periphery of RWH pond. Signages shall be displayed at various locations for the awareness. Fencing provides protection needed to develop and maintain a healthy plant cover around the pond. The marshy vegetation needed around ponds for satisfactory wildlife food and cover does not tolerate much trampling or grazing.

iii. Remedial measures for RWH Pond

Immediate and long term remedial measures: It is recommended that SV Trans treatment system should be constructed before the monsoon gets started in order to control the untreated surface runoff into the RWH. It is not a short term activity to be performed but it will serve the cause for longer duration in the rejuvenation activity of RWH pond.

SV Trans treatment system (SVT) is a root zone treatment system, it consists of filtration bed, microbial active treatment bed and highly effective rooted plants. The filtration system comprises of coarse gravel (size 40mm to 60mm), the large sized gravel, bed of thick coconut fiber mats supported by polyethylene nets, clay and silt soil, microbial active bed comprises of suitable bacteria culture which enhance the degradation of complex organic material into the simpler one thus providing nutrition to the so created ecosystem. This system has been designed with a purpose to address the excessive nutrient influx from the surface run off in & around the RWH pond at MSW site.

The system will be effectively placed in downward stream in a shallow trench within a landfill area where water flows towards the RWH Pond. The contaminated storm water passes through the SV-Trans Treatment System with the gravity effect before it enters the RWH Pond. All the contaminants get trapped into the SV-Trans Treatment System and help to reduce the pollution load entering into the RWH Pond. It is very easy to install, operate and maintain. No extra cost is required once it has commissioned. It requires zero maintenance cost in the later stage of the Project as it has self-rejuvenation capacity.

In order to the conversion of existing Municipal Solid Waste Sites into RWH Pond for the collection and storing of Rain Water to cater the water demand required for gardening purpose . Sunita Enviro has developed following given models and the SV-Trans Treatment System in order to allow the controlled surface runoff into the RWH Pond.

The significance of Vetivera is well known for the purification of surface runoff water. The bed will comprise of cultivated Vetivera and a wet land which will restrict the Surface Runoff to entre directly into the RWH Pond. The diagrammatic representation has been given in Fig. no. 3. This will be economically viable treatment scheme which can be effectively implemented and monitored.

The leachate generation is commonly seen process at any MSW disposal site, as the moisture content in the waste is in the range of 25 – 35%. But in monsoon the percentage of moisture always go up to maximum extent. Fig. 4 expresses how the leachate generation went up to maximum extent during monsoon. The threat of Ground Water contamination is always there as the percolation rate is higher. The same can be brought to the moderate level as per the Fig. 5. by capping the surface of MSW disposal site up to the used area by putting highly impervious Soil (Clay) having permeability of 10^{-9} to 10^{-6}.

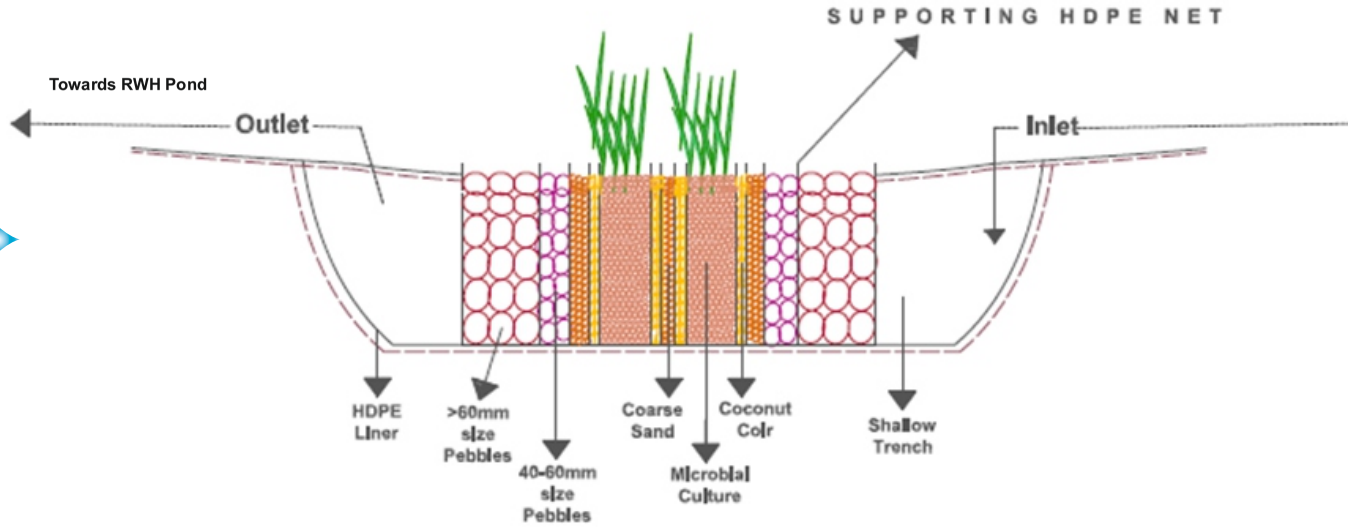


Fig. 3: **Sectional view of SV Trans System** (Vetivera Filtration System)

Note : Thickness of all beds is system specific.

Whereas; the leachate percolation can be controlled up to maximum extent by extending the impervious soil layer cover beyond the boundary of disposal site and making bund across the periphery of the disposal site to avoid the ingress of external runoff from the outside. The plantation will play very significant role in order to hold the soil and prevent it from erosion & in nutrient cycle; at the disposal site. The tentative model for the same has been given in Fig. 6 and Fig. 8.

The studies in the surrounding environs of RWH pond at MNP revealed that development of such pond has enhanced the surrounding ecosystem. Based on the study carried out and results obtained; it is been recommended that, such type of Rain Water Harvesting Pond as per site situation can be constructed on other landfill sites which are old and unscientifically managed.

SVTrans Treatment System model and Rain Water Harvesting Pond model has been developed by Dr. Pramod Salaskar, Mr. Prashant Dhotekar, Mr Chetan Patil and Dr. R.P. Athalye. It has been illustrated in following figures. It is simplest model suitable for construction of RWH pond on most of the solid waste disposal sites.

Diagrams:

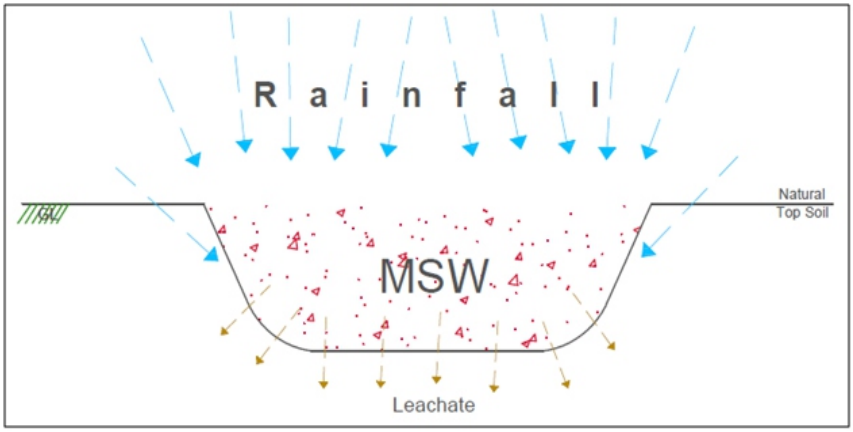


Fig. 4: Additional Leachate Generation (During Monsoon) because of open landfill site

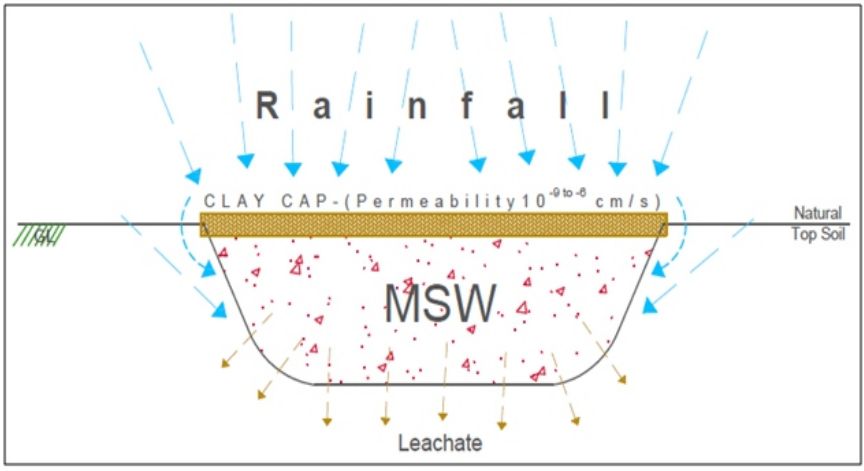


Fig. 5: Moderate Leachate Generation (During Monsoon) because of clay capping provided over landfill site

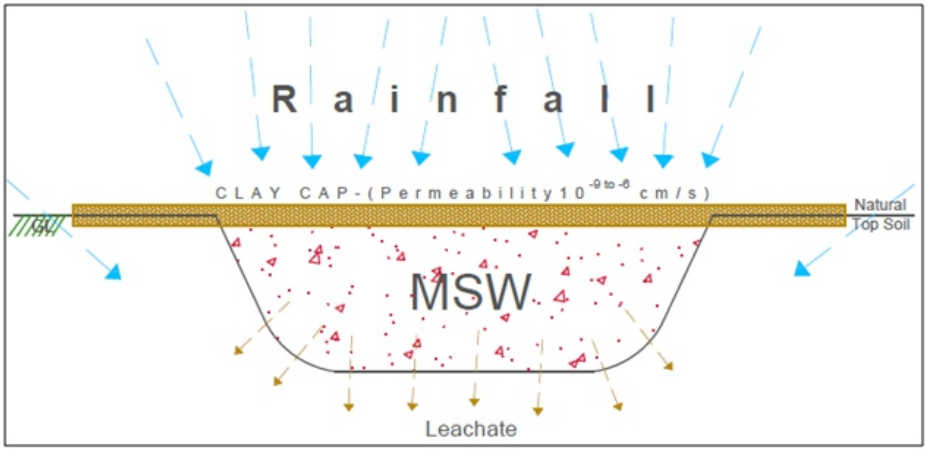


Fig. 6: Minimum Leachate Generation (During Monsoon) because of clay capping over landfill site and immediate surrounding area

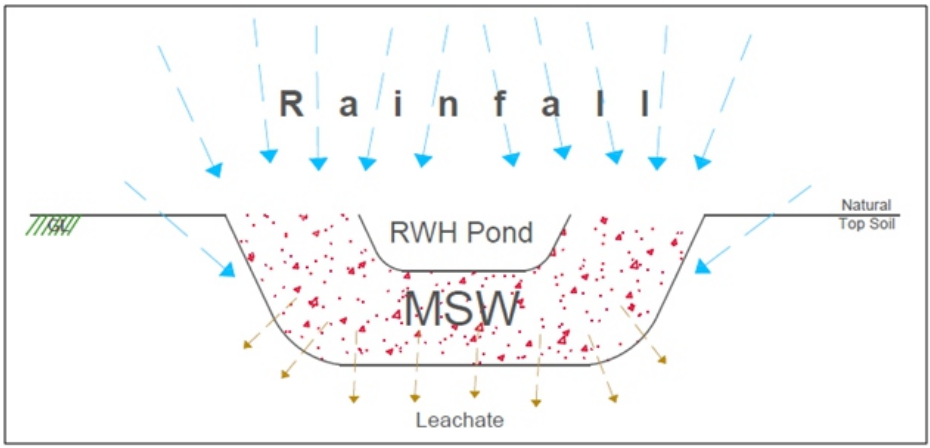


Fig. 7: Maximum Leachate Generation (During Monsoon) and percolation of the same into the sub-Soil.

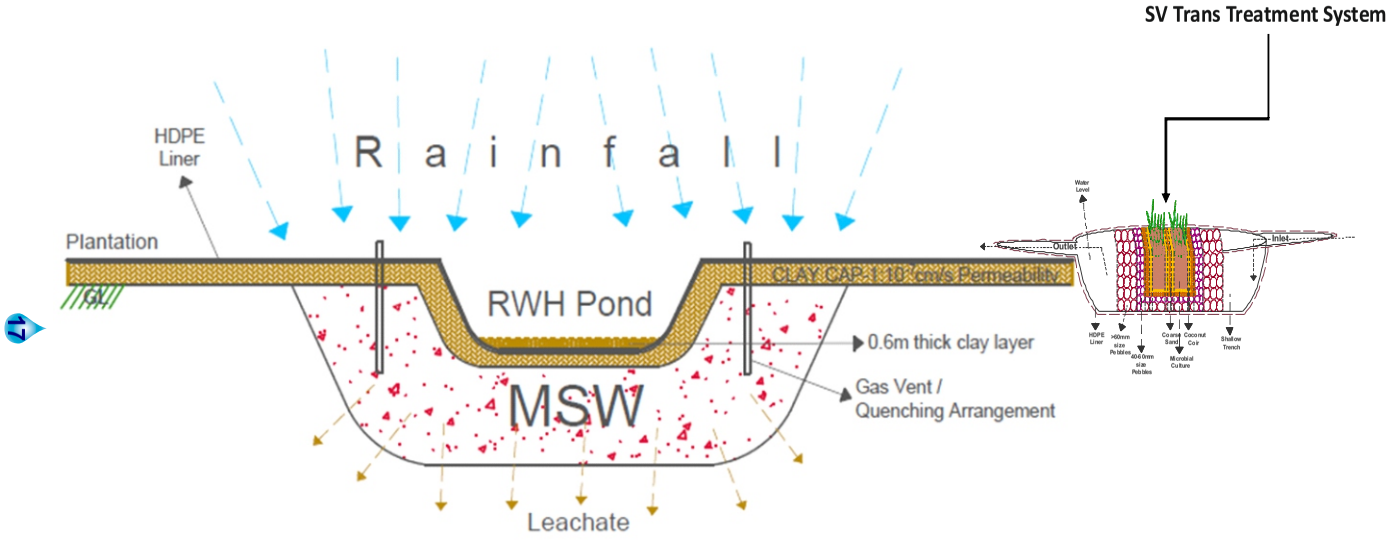


Fig. 8: Minimal Leachate Generation (During Monsoon) because of clay capping over landfill site and immediate surrounding area

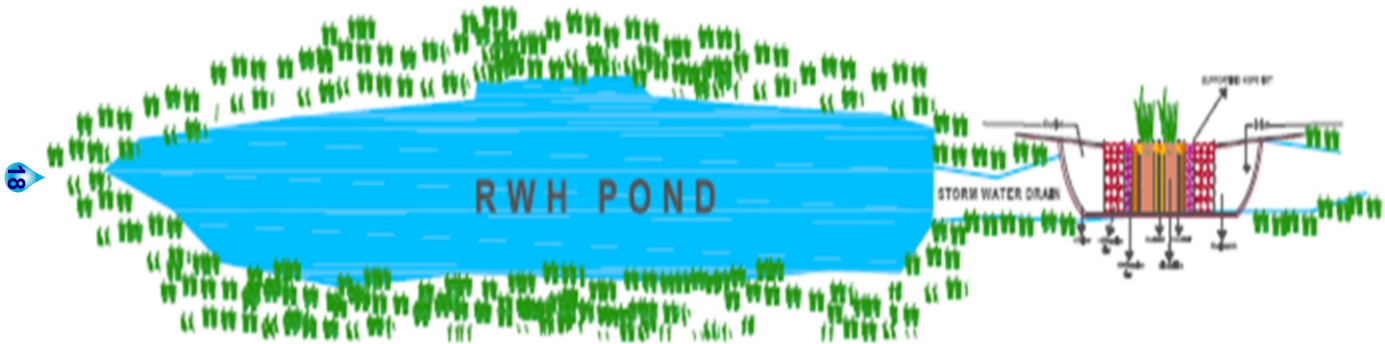


Fig. 9 : SV Trans Treatment System with RWH Pond along strom water drain

3.6. Location of sampling (depends on water spread area)

Location of sampling points is one of the main concerns for subsurface water quality testing of Rain Water Harvesting Pond. The location of sampling points should be selected considering the depth, runoff areas and proximity to other water bodies. Sampling is carried out from the stations/locations as given in table no. 1 usually between 08.00 am and 10.00 am. Frequency for sampling is defined in table no. 2.

A "surface" sample can be taken just below the surface (0.3 to 0.5 meters) to avoid surface scums. If the water depth at the sampling point is less than 0.5 meter, collect samples at a depth equal to one-third of the water depth measured from the water surface.

Table 1. Location for sampling points per water surface area

Lake or Pond Size (in acre)	Number of Sites /locations
< 10 Acres	3
10 < Acres ≤ 25	4
25 < Acres ≤ 50	5
50 < Acres ≤ 100	6
< 100 Acres	7

Table 2: Sampling frequency

Sr. No.	Type of Sample/Study	Frequency	Specific Months	No. of Stations	No. of Samples
1	RWH Pond Water	Quarterly	April /July /October /January	3 Stations	One Sample per Station
2	Soil from Catchment Area	Twice in a Year	October & May	4 Locations around the RWH Pond	One Sample (Composite)
3	Ecology and Biodiversity	Twice in a Year (Pre and Post Monsoon)	March & October	In and around the Pond	Monitoring of Flora and Fauna

To study the effect of seasonal variation on physico-chemical characteristics, also the above frequency is suitable to monitor the ecological health status of the RWH pond.

3.7 Monitoring Process

All samples should be collected in Polyethylene or Glass containers. The minimum 3-5 litre of water is required for water quality assessment. Also for soil analysis one kg of bottom sediment is required. The collected samples shall be tested in any Ministry of Environment & Forest & Climate Change /NABL accredited laboratory for the parameters as given in table no. 3, 4, 5 (a), 5 (b) and 5 ©

For Ecology and Biodiversity study an expert shall be deputed to monitor the seasonal variation and report shall be recorded accordingly.

Post completion Investigations for RWH Secured Landfill Pond

Type of Investigation	Suggested Scope of Work
Ground water	1. Minimum four wells – one up gradient, three down-gradient. 2. Collection of ground water samples (bimonthly) for water quality testing annually 6 samples from the nearest water body.
Surface Water	3. Collection of surface water samples (bimonthly) for water quality testing annually 6 samples from the nearest water body.

Suitability of RWH Secured Landfill Pond (RWH SLF Pond)

RWH Secured Landfill Pond is recommended only in

a) Old dumped MSW dumping sites.

b) Disposal site of Process remnants from Agro/Food based processing plants.

It is not suitable for Hazardous Waste landfills.

3.8 Performance evaluation of RWH Pond:

Table 3 - Prescribed Format for recording the physico-chemical Characteristics of RWH Pond

Sr. No.	Parameters	Unit	RWH Pond												Avg. Values	Pollution Discharge Standard	for Irrigation IS: 2296
			Station-I				Station-II				Station-III						
			Pre-monsoon	First Monsoon	Post-Monsoon	winter	Pre-monsoon	First Monsoon	Post-Monsoon	winter	Pre-monsoon	First Monsoon	Post-Monsoon	winter			
1	Colour	.....														...	...
2	Odour	.....														....	...
3	Depth	meter														.....	...
4	Water Temp.	°C														.....	...
5	Ambient Temp.	°C														....	...
6	Transparency	Cm														....	...
7	Turbidity	NTU														...	...
8	Dissolved Solids	mg/l														...	2100
9	pH	...														5.5 to 9.0	6.5 - 8.5
10	Total Hardness	mg/l														....	
11	Total Chlorides	mg/l														....	600
12	Dissolved Oxygen	mg/l														...	...
13	Total Alkalinity	mg/l														200	...
14	Phosphate	mg/l														5	...
15	Calcium	mg/l														...	...
17	Magnesium	mg/l														...	...
19	Sulphate	mg/l														...	1000
20	Silica	mg/l														...	...

21	Free Carbon Dioxide	mg/l														...	...
22	Nitrates Nitrogen	mg/l														...	...
23	Salinity	%														...	...
24	Oil & Grease	mg/l														...	...
25	Sodium	mg/l														...	...
26	Potassium	mg/l														...	...
27	Lead	mg/l														0.1	...
28	a) Net Pri. Productivity	mgC/m^3 /day														...	...
29	b) Gross Pri. Productivity	mgC/m^3 /day														...	...
30	BOD (5-days at 20 ^oC)	mg/l														30	...
31	C.O.D.	mg/l														250	...
32	M.P.N. / 100ml	---														...	...
33	Boron	Mg/l														...	2
34	Sodium Absorption Ratio	...														...	26

Table No. 4-Prescribed Format for monitoring of Trophic State Index

Parameters	Avg. Values (derived from Study)	Avg. Values Observed from Station I,II & III for the Month of May	Avg. Values Observed from Station I,II & III for the Month of October	Avg. Values Observed from Station I,II & III for the Month of February	Standard to be Observed
1	2	3	4	5	6
Name of Pond/ Lake					
Total Phosphorus mg/l					
Total Chlorophyll-a mg/l					
Secchi Depth in cm					
Total Phosphorus µg/l					
Total Chlorophyll-a µg/l					
Secchi Depth in meter					
TSI (TP)					
TSI /(T Chl)					
TSI (SD)					
TSI					
Trophic State					

3.9 Health Status of RWH Pond:

Fresh water ecosystems are dynamic and always exchange at matter and energies amongst the abiotic and biotic components is taking place. If these exchanges are affected due to excessive concentration of stress parameters such as dissolved solids, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), heavy metals etc. then it is claimed that water body is polluted. Stress indicators are quantifiable by using standardized laboratory procedures.

The Health status of water body is expressed as oligotrophic, mesotrophic, eutrophic and hyper-eutrophic depending on the abundance/bloom biotic components as an ecological manifestation of physico-chemical-biological interactions.

Table : 5: The significance of each class of pond mentioned above are:

Sr. No.	Categories	Characteristics
1	Oligotrophic	Clear, deep and free of weeds or large algae blooms, low in nutrients low primary productivity well-oxygenated waters, high transparency
2	Mesotrophic	Clear water, medium levels of nutrients, intermediate level of productivity, low algal growth
3	Eutrophic	High in nutrients, a large biomass, high biological productivity
4	Hyper-eutrophic	Very high in nutrients, low transparency, excessive algal blooms, low or no dissolved oxygen

Ref. Omkar Singh, National Water Academy,Pune (2010)

In case of RWH Pond constructed on the MSW site, during the initial 5-6 years, the status will be highly eutrophic. Regular monitoring will be required and maximum period shall be provided for stabilization.

Table 6: Use based classification of surface waters in India as given below:

Designated-Best-Use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1. Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6.0mg/l or more 4. Biochemical Oxygen Demand 5 days 20^{o}C 2mg/l or less
Outdoor bathing (Organised)	B	1. Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20^{o}C 2mg/l or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 to 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20^{o}C 2mg/l or less
Propagation of Wild life and Fisheries	D	1. pH between 6.5 to 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 to 8.5 2. Electrical Conductivity at 25^{o}C micro mhos/cm Max.2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l

Source: CPCB, 1978/2007-08

4. Ecological Quality Index (EQI) of Lake /Pond

Ecological Quality Index (EQI) indicates the health status of the fresh water body. Conducting water quality tests (basic and advanced) and biological assessment of the surrounding catchment area needs a lot of time, work and money – especially in the case of integrated methods of water quality assessment. The development of simple Ecological Quality Indices (EQI) is an easier, cheaper and less time-consuming way of water quality and biological assessment of lakes and ponds.

Ecological Quality Index is calculated on the basis of Water Quality Index (WQI), Carlson's Trophic State Index (TSI), and Simpson's Diversity Index (SDI). Out of these three, Quality Index (WQI) and Carlson's Trophic State Index (C.TSI) have inverse relation with Ecological Quality and Simpson's Diversity Index (SDI) has direct relation with Ecological Quality. Hence a combined Ecological Index was evolved as below:

$$\text{Ecological Quality Index (EQI)} = \frac{[\text{Status no. for EQIofC.TSI} + \text{Status no. for EQI of WQI} + 1/\text{SDI}]}{3} \quad \ldots\ldots\ldots\ldots(1)$$

Where,

EQI = Ecological Quality Index

C.TSI = Carlson's Trophic State Index

WQI = Water Quality Index

SDI = Simpson's Diversity Index

The status number of Carlson's Trophic State Index (C.TSI) and Water Quality Index (WQI) are shown below, where as Simpson's Diversity Index (SDI) was considered as it should not be less than 0.2. As Simpson's Diversity Index (SDI) has direct relation with ecological quality for calculating EQI, its inverse 1/SDI has been used.

The status number (points) for Carlson's Trophic State Index (C.TSI) and Water Quality Index (WQI) are given according to the status of the pond/lake they indicated. This has been explained in Table no. 7 & 8 as given below:

Table 7 Status no. for EQI of Water quality index (WQI)

Water Quality Index	Status	Status Number (used for EQI)
0 – 25	Excellent	1
25.1 – 50	Good	2
50.1 – 75	Average	3
75.1 – 100	Poor	4
Above 100	Very Poor	5

Table 8 Status no. for EQI of Carlson's Trophic State Index (TSI)

Carlson's TSI Range	Trophic State	Status Number (used for EQI)
10-30	Oligotrophic	1
31-50	Mesotrophic	2
51-70	Eutrophic	3
71-90	Hyper-eutrophic	4
>90	Extreme Hyper-eutrophic	5

4.1 Simpson's Diversity Index:

A community dominated by one or two species is considered to be less diverse than the one in which several different species have a similar abundance. Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases.

$$D = 1 - \left(\frac{\Sigma\, n(n-1)}{N(N-1)} \right)$$

n = the total number of organisms of a particular speciesN = the total number of organisms of all speciesThe value of ***D*** ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity.

4.2 Water Quality Index (WQI):

The index is basically a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality in a given water basin, such as a lake, river, or stream. The Water Quality Index (WQI) is calculated by using Deiniger and Maciunas method of 1971 (Mishra and Patel, 2001). Five parameters are taken for calculationof water quality index: pH, Total Hardness, Total Chloride, B.O.D. and MPN.

$$WQI = Antilog \sum_{N=1}^{10} W.log\, q \qquad \text{.....(1)}$$

Where,

Wn = Unit weight for nth parameters; calculated as

Wn = K/Sn

Sn = (n = 1,2,3,,....6) HDL for nth water quality parameters;

The quality rating (qn) for the nth water quality parameters may be obtained for all parameters as follows; except pH (Tiwari and Manzoor Ali, 1986).

$qn = 100*Vn/Sn$ .... (2)

Where, Vn = Observed value;

Sn = Recommended standard value for n^{th} parameter.

Equation (2) ensures that qn = 0, when a pollutant (nth parameter) is absent in the water, while qn = 100, if the observed value of parameter is just equal to its desirable limit or standard for drinking water.

For pH the quality rating qpH can be calculated from the relation

$$q_{pH} = 100 \frac{(v_{pH} - 7.0)}{(8.5 - 7.0)} \quad \text{.......... (3)}$$

Where, vpH is observed value of pH and the (-) means simply the numerical difference between vpH and 7, ignoring its algebraic sign. 8.5 is the permissible value of pH and the pH of neutral water is 7, which is ideal value. The standard water quality index and status are given in Table 1.

WQI = antilog [SUM (Wn.log.qn)]

Wn = Unit Weight for the nth parameter

Sn = (HDL) Highest Desirable Level

In (Ideal value) for all remaining parameters = 100

K = Proportionality constant = 0.87858

qn = Quality rating for the nth parameter

Vn = Observed value

Table 8 Methodology for calculation of Water Quality Index of RWH Pond

Sr. No.	Parameter	Sn	Wn=K/Sn	Vn	qn=(Vn/Sn)100	log(qn)	Wn.log(qn)
1	pH						
2	Total Hardness						
3	Total Chloride						
4	BOD						
5	MPN						
						SUM	
						WQI	

4.3 Trophic State Index (TSI) of Carlson:

The Carlson TSI is divided into four main lake productivity categories: *oligotrophic* (least productive), *mesotrophic* (moderately productive), *eutrophic* (very productive), and *hypereutrophic* (extremely productive). The productivity of a lake can therefore be assessed with ease using the TSI score for one or more parameters (Table 8). Mesotrophic lakes, for example, generally have a good balance between water quality and algae/fish production. Eutrophic lakes have less desirable water quality and an overabundance of algae or fish.

The index ranges from 0-100 and has the advantage over the use of raw variables (Decimal fractions are converted to units of 10). Any of the three variables can be used to classify the water body. Chlorophyll-a is given highest priority for classification and is the most accurate of the three at prediction of algal biomass.

Carlson's Trophic State Index (TSI):

TSI < 30	Classic Oligotrophy, clear water, oxygen through out the year in the hypolimnion
TSI < 30 – 40	Deeper lakes still exhibit classical oligotraphy, but some shallower lakes will become anoxic in the hypolimnionduring the summer.
TSI < 40 – 50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TSI < 50 – 60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnion during the summer, macrophyte problems evident and warm-water fisheries only.
TSI < 60 – 70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI < 70 – 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
TSI < 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.

Calculation for the Trophic State Index (TSI) of Carlson:

TSI for Chlorophyll-a (CA) TSI = 30.6 + 9.81In Chlorophyll-a (ug/l)

TSI for Secchi depth (SD) TSI = 60 - 14.41In Secchi depth (meters)

TSI for Total phosphorus (TP) TSI = 14.42 In Total phosphorous (ug/l) + 4.15

Where,

ln = natural logarithm

TSI = Carlson Trophic State Index

$$\text{Carlson's TSI} = \frac{[\text{TSI (TP)} + \text{TSI (CA)} + \text{TSI (SD)}]}{3}$$

Table no. 12. Methodology for calculation of Trophic State Index (TSI) of RWH Pond

Sr. No	Name of Pond/ Lake	Total Phosphorus mg/l	Total Chlorophyll-a mg/l	Secchi Depth in cm	Total Phosphorus µg/l	Total Chlorophyll-a µg/l	Secchi Depth in meter	TSI (TP)	TSI (T Chl)	TSI (SD)	TSI	Trophic State
1												
2												
3												
4												

The Ecological Quality Index has inverse relation with Ecological quality status shown in table 9. Lower the EQI, better is ecological quality and health of the water body.

Table 13 Standard Ecological Quality Index (EQI)

Ecological Quality Index	Ecological Quality Status
0 – 1	Excellent
1- 2	Good
2 – 3	Average
3 – 4	Poor
4 – 5	Very Poor

Table . 14 Methodology for calculation of Ecological Quality Index (EQI) of RWH Pond

Sr. No.	Name of the Lake/Pond	Average value of WQI	Status no for EQI of WQI	Average value of Carlson's TSI	Status no for EQI of C.TSI	Simpson's Diversity Index (SDI) (should not be less than 0.2)	1/SDI	Ecological Quality Index	Ecological Quality Status
1									
2									
3									

Details formulas have been provided in section 4.1, 4.2, 4.3

Conclusion

The results of present pilot project executed at the MNP are indicative that the old & closed MSW sites can be restored ecologically & economically following the guidelines as suggested in this manual for construction of RWH pond. Also the water thus harvested was found to be fit for the irrigation purpose as per the CPCB guidelines. The harvested water not only being utilized for gardening & dousing fires: thus created artificial water body altogether supported the overall surrounding ecology.

Glossary of technical terms used :

Bentonite **:** Bentonite, available in either powdered or granular form, is fine-grained clay that absorbs water and swells from 8 to 20 times its original volume.

Excavated Pond: A reservoir constructed mainly by excavation in flat terrain. A relatively short embankment section on the downstream watercourse side may be necessary for desired storage amount.

Leachate : A leachate is any liquid that, in the course of passing through matter, extracts soluble or suspended solids, or any other component of the material through which it has passed.

Pond : A still body of water of limited size either naturally or artificially confined or usually smaller than a lake.

Pond Liners **:** Flexible membranes such as high density polyethylene, vinyl, or butyl rubber is an effective but costly way to reduce excessive seepage losses in recreational ponds.

Scūm : A layer of something unpleasant or unwanted that forms on top of a liquid or body of water

Sealing **:** The process used to close openings in soil materials and prevent seepage of water.

Storage volume: The total volume available from the bottom of the reservoir to the top of Dam

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The shoreline of a well-designed pond is protected from erosion by the addition of stone

The use of Vetiver Grass Wetlands for storm water treatment system

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