

Reduction of Evaporation Losses of Water using High Density Polyethylene Shade Balls

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Abstract : Water is one of the nature's precious gifts, which sustains life on earth. About 71% of earth surface is covered with water and the ocean holds about 97% of all earths' water. Remaining 3% is freshwater. This 3% freshwater is categorized as 68.7% is covered with icecaps and glaciers, 30.1% is groundwater and remains only 0.3% surfacewater.

This 0.3% surface water is categorized as 87% water covered by lakes, 11% swamps & river 2% consume by living organism. The water covered by lakes and reservoirs is useful for drinking and many other purposes and may subjected to losses also. Global warming and the increasing concentration of greenhouse gases in the Atmosphere will affect temperature which results in faster rate of evaporation of potable water. This change has direct effect on reservoirs storage and availability of water resources. Many methods were proposed to reduce evaporation from open Reservoirs. These Shade Balls methods can be named as physical method. Research was done to evaluate the effectiveness of these methods in evaporation reduction from Reservoirs. Published research revealed that the physical methods can reduce Evaporation losses effectively, it also effect the pH value, Total Dissolved Solid, Dissolved oxygen of water & algae growth of water including survival of fish.

Index Terms - Global warming, Rate of evaporation, Reservoirs

1. INTRODUCTION

Water is one of the nature's precious gifts, which sustains life on earth. Civilizations over the world have perished depending upon the availability of this vital resource. Water has been worshiped for life nourishing properties in all the scriptures.

About 71% of earth surface is covered with water and the ocean holds about 97% of all earths' water. Remaining 3% is freshwater. This 3% freshwater is categorized as 79% is covered with icecaps and glaciers, 20% is groundwater and remains only 1% surface water. This 1% surface water is categorized as 52% water covered by lakes, river 1%, 1% consume by living organism, 38% is soil moisture and 6% atmospheric water vapor. The water covered by lakes and reservoirs is useful for drinking and many other purposes and may subjected to various losses also.

In the earlier days availability of water was taken for granted. It is now being realized that water is not an unlimited resource and cannot be produced or added as and when required, by any known technological means. The other important limitation is that the availability of water over the years depends upon the variation of precipitation. Thus water may be abundant during monsoon season and scarce in non-monsoon season, when most needed. The life of man, therefore, lies in his ability to modify the pattern of availability of water to suit needs. One of the commonest forms of such modification is storage of water during monsoon season for eventual use in lean season. The traditional methods are big storage in natural or artificial tanks. The large numbers of storages have been constructed. Due to high temperature, about one third of the the evaporation losses have been found to be substantial. Therefore, it is necessary to minimize evaporation losses in the storages/water bodies.

The need for prevention of enormous evaporation losses assumes greater significance, in view of the predictable scarcity of water; the country will be facing in future. It has been assessed that against the utilizable water resources of the order of 1093 billion cubic meter, the requirement by 2025 AD to be met from surface water resources will be around 1123 billion cubic meter, thereby surplus by just 30 billion cubic meter.

Due to intense agricultural practices, rapid increase in population, industrialization and urbanization etc., scarcity of water is being increasingly felt. The situation becomes grave in the arid and semiarid regions specially during droughts, when general scarcity of

water is compounded by high evaporation losses from open water surfaces of lakes and reservoirs. During severe drought conditions of 1987, the water scarcity in Gujarat and some other parts of the country was so severe that even drinking water had to be carried by trains to the affected areas. In the present scenario of utmost strain on the water resources, of the country, it becomes necessary to conserve water by reducing evaporation losses.

As per I.S. 6939:1992 Evaporation is the process in which liquid changes to gaseous state at free surface below the boiling point through the transfer of heat and wind energy. Evaporation rates closely follow the climatic seasons, and reach their peak in the summer months of April and May and the central areas of the country display the highest evaporation rates during this period. The annual potential evaporation ranges between 150 to 250 cm over most parts of the country.

1.1 Assessment Of Evaporation Losses In India

As per available records, assessment of evaporation losses in the country was first made by L.A. Ramdas and presented in Symposium of Evaporation control in 1966.

The assessment was based on the following assumptions:

- Area of arid, Semi arid and long dry spell regions of India - 2,000,000 Sq.km
- Estimated water area in this region (1%) - 20,000 Sq. km.
- Estimated area where film application may be feasible - 2,000 Sq.km.
- The evaporation loss from the above area - 6,000 MCM

The National Commission on Agriculture (1976) had estimated that the annual evaporation losses from reservoir surfaces will be of the order of 50,000 MCM.

Central Water Commission in their publication "Status Report on Evaporation Control in Reservoirs, 1988" had indicated that on an average there is a loss of about 450 MCM of water every month from an area of 2,000 Sq.km.. which amounts to an annual loss of 5,400 MCM. The Water Management Forum (WMF), a national body of the Institution of Engineers (India), in their publication "Water Conservation by Evaporation Control, 1988" had indicated that on the Indian sub-continent the estimate total loss of water from large, medium and small storages will be to the tune of 60,000 MCM, which according to WMF would be adequate to meet the entire municipal and rural water needs of India by 2000 AD.

The assessment of evaporation losses had been reviewed by CWC in 1990. Average annual evaporation from reservoirs/water bodies in India varies from 150 cm to 300 cm. The total surface area of existing large and medium storages, tanks and lakes in the country is of the order of 12,000 Sq.km.. This is likely to increase to about 25,000 Sq.km. at the ultimate stage of development. Assuming annual evaporation loss rate of 225 cm, the evaporation loss from existing water bodies works out to 27,000 MCM. In the ultimate stage, the evaporation losses may be of the order of 56,000 MCM. Thus, likely evaporation losses appear to be high, considering capital costs involved in creation of storages.

It may not, however, be possible to take remedial measures of evapo-retardation on all storages/water bodies. Assuming even 20% of the above area falls in scarcity and drought areas, it may be necessary to tackle around 2,400 Sq.km. of surface area in the present stage and about 5,000 Sq.km.. at the ultimate stage. It is further seen that about 30% of evaporation retardation may be achieved by known evapo-retardation methods.

1.2 Factors Affecting Evaporation

Evaporation is a process by which a liquid changes into vapor form. Water molecules are in constant motion and some have the energy to break through water surface and escape into air as vapor. Evaporation in general is a beneficial phenomenon in regulating global water balance through the hydrological cycle and it is the same phenomenon contributing to massive losses from water bodies.

Control of evaporation from land based water bodies, has thus remained one of the main planks of water conservation strategies. This assumes greater significance in arid regions, where water scarcities are already a common problem.

A number of factors affect the evaporation of water from open water surface, of which the major are:

- 1) Water Surface Area : Evaporation is a surface phenomenon and the quantity lost through evaporation from water stored, therefore, depends directly on the extent of its surface exposed to the atmosphere.
- 2) Temperature : The temperature of water and the air above it affect the rate of evaporation. The rate of emission of molecules from liquid water is a function of temperature. The higher the temperature, greater is the rate of evaporation.
- 3) Vapor Pressure Difference : The rate at which molecules leave the surface depends on the vapor pressure of the liquid. Similarly, the rate at which molecules enter the water depends on the vapor pressure of the air. The rate of evaporation therefore depends on the difference between saturation vapor pressure at the water temperature and at the dew point of the air. Higher the difference, more the evaporation.
- 4) Wind Effect : The greater the movement of air above the water, greater is the loss of water vapor. Experimental studies on the relationship between wind speed and evaporation show direct relationship up to a certain value of wind velocity beyond which perhaps the relationship does not hold good. Factors like surface roughness and dimension of the water body are reported to have an important role to play.
- 5) Atmospheric Pressure : Atmospheric pressure is very much related to other factors affecting evaporation. It is, therefore, difficult to assess its effect separately. The number of air molecules per unit volume increases with pressure. Consequently with high pressure, there is more chance that vapour molecules escaping from the water surface will collide with an air molecule and rebound into the liquid. Hence evaporation is likely to decrease with increasing pressure.
- 6) Quality of Water : The salt content in water affects the rate of evaporation. Experimental studies show that the rate of evaporation decreases with increase in salt content in water. In the case of sea water, the evaporation is 2 to 3% less as compared to fresh water, when other conditions are same.

1.3 Necessity

Now a days the temperature is increasing day by day and the rate of evaporation is also increasing. This increase in temperature is directly affecting our valuable water resources which are already less, so it is our responsibility to preserve this water resources for the present and future needs. For achieving this many methods are invented and studied to control evaporation of open water storages.

This chapter deals with the one of the experiment to control evaporation by using high density polyethylene 'Shade Balls' to achieve control over evaporation from open water storages.

Example :- Upper Wardha Dam

Live storage 6500 M.C.M

Surface area 97.48 sq.km

Assuming 1 mm evaporation,

The volume of evaporated water 97480 cum.

This amount of water can fulfill Water demand of 722074 people.

2. LITERATURE REVIEW & RELATED WORK

2.1. Los Angeles Reservoir, California.

In 2008, the Los Angeles Department of Water and Power (LADWP) has taken a surprisingly low-tech approach to water conservation, by covering the LA reservoir in 96 million black "shade balls." It's an attempt to combat water loss through evaporation, and to heighten water quality.

California's water shortage are now believed to be so severe that the state would now require 51 cm of rainfall that's equivalent of an entire year's rainfall. The LA reservoir has become an even more vital resource, spanning an impressive 175 acres (71 hectares) and holding roughly 12.5 billion liters of water enough to support the entire city of Los Angeles for up to 3 weeks.

Each ball costs 36 cents, with US \$34.5 million. While this may sound like a lot of money to turn LA's largest reservoir into a massive watery ball pit, other water saving alternatives would have proven far more costly to implement. Another option that had been under consideration would have seen the reservoir separated into two distinct basins with the use of bisecting dam and protected with the floating cover, at the much greater cost of \$300 million.

The unusual strategy represents a significant cost saving around \$250 million US gallons (1.14 billion lit.) of water to evaporation. Simultaneously the shade balls will increase water purity by preventing contamination via wildlife and dust, as well as reducing sunlight-triggered chemical reactions.

It is estimated that the sheer quantity of water saved under the initiative will be sufficient to provide drinking water to sufficient to provide drinking water around 8100 LA resident for an entire year. Scroll down for a video showing the release of 20000 shade balls into the LA reservoir.

In 2014 and 2015, the LADWP deployed 96 million shade balls on its largest reservoir in response to the United States Agency's surface water treatment rule, which requires large reservoirs to be covered. The LADWP claims that in addition to reduce evaporation they will also reduce UV radiation by products and algae growth. [1]

2.2 Irrigation Development Division, Mumbai:

This Division is one of the first few premier organizations in India to carry out investigations during end of 1957 with Cetyl alcohol. The experiments were carried out in Kasurdi Tank (capacity 0.42 MCM) and Bhandgaon Tank (capacity 0.32 MCM) both situated near Pune. Cetyl alcohol was used for evaporation suppression studies and was dispensed on water surface in a powder form by a hand-operated duster, mounted on a boat. A quantity of 0.91 kg of Cetyl alcohol was spread in four rows in each of the two tanks covering the entire area of the tanks.

The following data were collected during the field experiments:

- i) water level of the tank
- ii) inflow into the tank
- iii) outflow by way of seepage and for irrigation
- iv) evaporation with and without Cetyl alcohol from pan evaporimeter of 3m dia kept by the side of the tank and
- v) wind velocity, air and water temperature in different periods of the day.

The saving in water due to the application of Cetyl alcohol was found as 30% in Bhandgaon Tank and 14% in Kasurdi Tank.

2.3. Central Soil & Materials Research Station, New Delhi

This Research Station, earlier known as Central Soil Mechanics and Concrete Research Station had conducted studies with chemical WER for a period about eight years from 1958 to 1966 on Badkhal Tank, Haryana; Takhat Sagar Maota and Sagar tanks, Rajasthan and Mir Alam tank, A.P. The chemicals used were mostly Cetyl or Cetyl Stearyl alcohol and were dispensed in the solution or emulsion form. As a trial,

powder form of WER was also used. Mineral turpentine as a solvent and indicator oils having film pressure in the range of 11 to 40 dyne/cm were used. A film pressure of 24 dyne/cm is reported to have been maintained at these sites. Meteorological observations like temperature, wind direction, wind velocity were regularly observed during the studies. A contour survey of the tanks was also undertaken to know the quantity of stored water. Besides, gauges were fixed in different parts of the tank to record water level. Pan evaporimeters were also installed at the site.

2.4. Central Public Health Engineering Institute, Nagpur:

This Institute had conducted studies on three lakes namely Walwhan, Vihar and Gorawara as per suggestions from Australian experts and guidance from C.S.I.R. in the mid-sixties. The Walwhan Lake had a water spread area of 0.22 Sq.km.. at FRL Meteorological data such as maximum and minimum temperature, wind direction, wind velocity, rainfall were reported to have been recorded daily at fixed interval of time. Besides, gauges were fixed in different parts of the tank. Cetyl alcohol as evaporation retardant and indicator oils from M/s Shell Company having surface pressure in the range of 16-40 dyne/cm were used. While the Cetyl alcohol was dispensed in the form of emulsion in the Walwhan and Vihar lakes, powder technique was used in the Gorawara Tank. The powder was dispensed by means of a duster fitted on the boat. The inflow and outflow characteristics of the lakes were regularly recorded by measuring the water level differences.

Inferences drawn from the studies are given below:

- i) The chemical required ranged between 0.02 to 0.05 kg/hectare/day to maintain the film pressure of 21 dyne/cm in Walwhan and Vihar lakes, while in Gorawara tank it was 0.05 kg/hectare/day.
- ii) The evaporation saving ranged from 3.7 to 17.8% for the period of study in Walwhan Lake, 0.25 to 20% in Vihar lake and 8-16% in Gorawara Tank.

3 Objective

This study has been performed keeping in view the following objective:

- To reduce evaporation loss of reservoir economically.
- To fulfill water demand in summer season.
- To reduce the treatment cost of water.
- To reduce the growth of and algae in the reservoir.
- To enhance the fish crop.
- To prevent water from deposition of dust.

4.PROPOSED WORK

4.1 High Density Polyethylene (HDPE) Shade balls

The shade balls are made of high density polyethylene (HDPE) and resin with a black colorant that inhibits ultra-violet light degradation. All shade balls have a 4-inch outer diameter. The balls used in this experiment weight 30 grams and are filled with 160 ml of tap water to give them increase in self weight so they are not blown away by wind.

The raw material required for manufacturing shade balls are listed below:

- a) High density poly-ethylene (HDPE)
- b) Carbon black
- c) Ethylene vinyl acetate (EVA)



Shade ball

- a) High density poly-ethylene (HDPE) 95%

High Density Polyethylene (HDPE) is a thermoplastic material which is in granular form. The plastic used to make shade balls is food grade and brings no known issues for health and safety. As a matter of fact, the same plastic is used for drinking water bottles, food containers, water pipes, etc. The balls comply with federal standards and are considered safe to be in contact with drinking water.



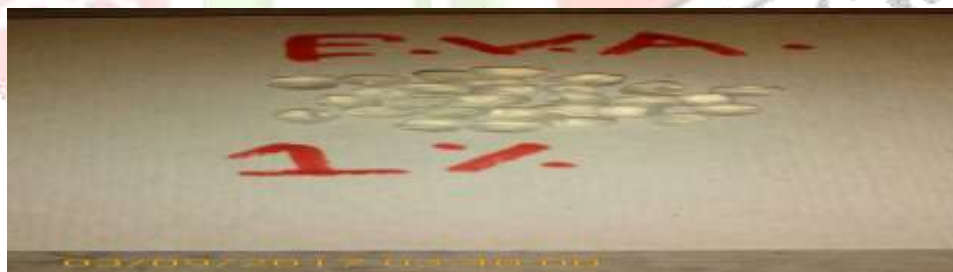
b) Carbon Black 4%

Carbon black is a material produced from incomplete combustion of petroleum products such as coal, tar, vegetable oil, etc. Carbon black has a high surface area to volume ratio. Carbon black is mainly used as a reinforcing filler in tires and other rubber products, plastic, paints, and inks. Carbon black is used as a pigment.



c) Ethylene Vinyl Acetate (EVA) 1%

Ethylene vinyl acetate is a thermoplastic material like low density polyethylene. It has properties of low density but increased gloss, softness, and flexibility. The material is generally non-toxic. It provides flexibility to the ball and increases its strength to some extent. It also increases the melting point of the plastic material in which it is added. It also provides protection to the ball from ultra-violet rays.



4.2 Construction of shade ball

Shade balls are made up of high density polyethylene with carbon black and ethylene vinyl acetate (EVA) that inhibits ultraviolet light degradation. The proportion of HDPE is 95%, carbon black 4%, and EVA is 1% in percentage.

4.2.1 Working of shade balls

The shade ball acts as a floating cover on the water surface and prevents the entry of sun rays. It also obstructs the flow of wind on the surface of water. These are the major factors causing evaporation of water, which are controlled by shade balls as a cover. Due to this, the algae growth is also reduced, which further results in reducing the treatment plants' working load. The shade balls protect water quality by preventing chemical reactions. Filled with 60ml of drinking water to give them weight so they are not blown by wind and prevent the heating of the ball due to external temperature.

4.2.2 Method for determination of evaporation losses : Indian Standard Pan

The test was conducted as per Indian meteorological standards. Two readings were taken in both pans covered and uncovered pan on standard time 8:30 AM and 5:30 PM. The evaporation is measured in **millimeter**. (mm)

The standard pan, also known as modified class A Pan, specified by IS:5973-1970 is made of 0.9 mm thick galvanized iron sheet. It is 122 cm in diameter and 25.5 cm deep. It is tinned inside and painted white outside. It is placed on a 10 cm high square platform of 122.5 cm width made of wood. A fixed Point is kept in pan to indicate the water level. The top of pan is fully covered fully with a hexagonal mesh of galvanized iron to protect it from birds. It is filled with water to depth of 19 cm. A calibrated cylindrical measure is use to add or remove water in order to maintain the water level in the pan to a fixed mark indicated by the pointer gauge in stilling well. The details of the Indian standard pan are given in figure below. The point co efficient ranges from 0.65 to value of 1.10 and an average value of 0.8 is generally recommended.



Pan A (uncovered pan)



Pan B (covered pan)

4.2.3 Procedure :

The pan evaporation test was conducted on two pans of same specification pan A is uncovered pan and pan B is covered with shad balls

- Pan of same specification are placed on wooden platform of 100mm. height and 1.5 meters apart. The platform is placed on fairly levelled ground.
- Both the pan are filled with the same water samples.
- The evaporation is measured in the stilling well the water is filled up to depth 190 mm. (i.e. up to depth of fixed point gauge)

- The evaporation is measured by adding water required to match the level of fixed point gauge. With the help of calibrating container of 12.5 cm in diameter and 25 cm. in height. 10 mm height of water in the container is 1 mm. in the pan.

4.2.4 Sampling pits:

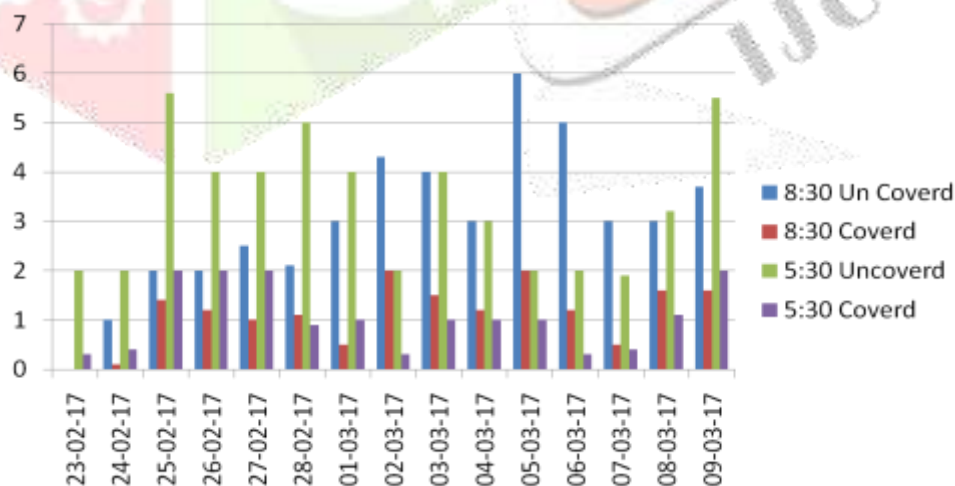
- A job layout is performed for position of pits and pan.
- Firstly we excavated four pits of dimension 1 cubic metre each by the means of excavating mechanical gauges.
- This pits are kept apart from each other at a distance of 1.5 m each.
- After that carpets are placed along the surface of pit so that water in it does not percolate into the earth.
- Then two pits are kept as it is i.e. only filled with water and in another two pits shade balls are placed.
- The water in the pits is used for sampling purpose i.e for determining physical and chemical properties.
- Various types of tests are performed on this samples.



Photograph of total setup of Project

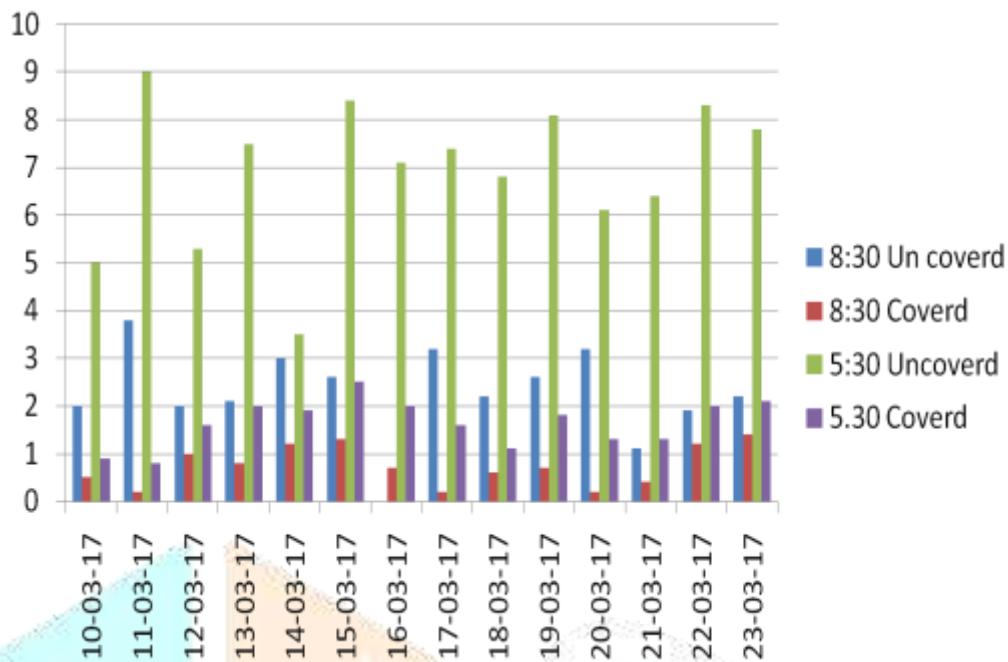
4.3 PERFORMANCE ANALYSIS

4.3.1 Results of Evaporation:



x-axis : Evaporation in mm. (Millimeter)

y-axis : Dates of Measurement of Evaporation for difference timings (AM & PM) .



x-axis : Evaporation in mm. (Millimeter)

y-axis : Dates of Measurement of Evaporation for difference timings (AM & PM) .

Graphical presentation of evaporation losses of covered & uncovered pan.

Test Results for pH of water :

Days	Uncovered Pits	Covered Pits
First 14	10.3	8.7
Next 14	10.7	8.5

Table No.1- pH test result.

Test result for Total Dissolved Solid :

Days	Uncovered Pits (mg/lit)	Covered Pits (mg/lit)
First 14	0.75	0.34
Next 14	0.87	0.1

Table No.2- T.D.S. test result.

Test result for Dissolved Oxygen :-

Days	Uncovered Pits (mg/lit)	Covered Pits (mg/lit)
First 14	7.8	4.3
Next 14	7.5	4.4

Table N0.3- Dissolved Oxygen test result.

4.4 Application

The floating cover method of shade balls can be used for lakes, reservoir, swimming pools, fish crop tanks and farm pond.

Conclusion :

The evaporation losses in uncovered pan can be reduced by 80 to 85 % by adopting shade balls as floating cover. Reduction in algae growth is achieved by using shade balls. No harmful effects found on fish crop. This method is economical as compared to other evaporation control methods. It can be adopted in farm ponds & reservoirs. The balls can be recyclable and it can be reused after its use. The shade balls do not react with water and hence it does not affect water quality. By adopting this method the cost of water treatment can be reduced to some extent. The pH of water of covered pits are found to be at the amount of drinking purpose. The Total Dissolved solid decreased in covered pits but the dissolved oxygen get depleted due to layer of balls on the top surface of water.

References :

- [1] Indian standard 5973:1998 Pan Evaporimeter specification.
- [2] Indian standard 6939 :1992 Methods for Determination of Evaporation From Reservoirs.
- [3] Indian standard 14654:1999 Minimizing Evaporation Losses From Reservoir Guideline.
- [4] Indian standard 10500: 2012 Drinking water specification .
- [5] Government of Maharashtra WATER RESOURCES DEPARTMENT WATER YEAR 2012-2013-2014.
- [6] CWC (Central Water Commission), India (1990), Evaporation Control in Reservoirs.
- [7] India Meteorological Department Publication – Evaporation data of Observatories in India 1980.
- [8] National Water Policy-2002, Ministry of Water Resources, Govt. of India. Report on evaporation control studies conducted by Chennai Metropolitan, Water Supply Sewerage Board, Chennai.
- [9] Water Conservation by evaporation control retardants and their applications, Water Management Forum, Gandhinagar, Gujarat, 1988.