INTRODUCTION TO INNOVATIVE PROJECTS WINTER SEMESTER 2020

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Title: Use of Shade Balls for Reservoir Water Quality Management

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Abstract

This project work on the use of shade balls for reservoir water quality management aims to solve a real world problem that is to prevent the contamination of purified water when it is stored in man-made reservoirs. The project deals with the composition and chemical structure of shade balls. Its manufacturing process and an estimate production liability. The process through which the shade balls prevent contamination will also be discussed. The suitable areas of its application along with a comparative view of existing techniques is one of the key points to be looked on. Overall, the newness and effectiveness of this particular idea and its advantages will also be a vital part of this project work.

Introduction

Fresh drinking water is not available in abundance in the world; hence the use of filtration and purification of saline water comes into play. Saline water when filtered is virtually harmless but when it is stored in reservoirs and other water storage containers, it becomes dangerous for consumption, defeating the purpose of filtration and purification procedures. To overcome this real-world scenario, we will identify and state the reason for the contamination and also use a cheap, long lasting and cost-effective technique to avoid and minimize the contamination of the stored water.

Composition of the shade balls:

Objectives:

- *Effectiveness*
- *Cost*
- *Recyclable*
- *Ease in manufacturing*
- *Eco-friendly*

<u>Density:</u>

The density of water is around 1 g/cm^3 so in order to get the maximum effect from the shade balls, the density of shade balls should be less than half of the water (i.e. 0.5g/cm^3) . This thing is explained here:

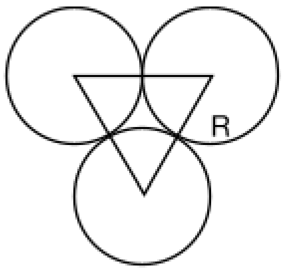


Fig 1.1

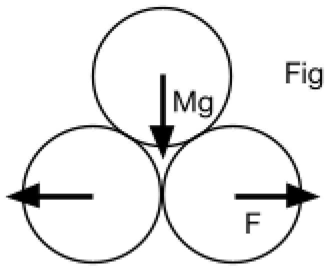


Fig 1.2

The area covered by shade balls is calculated by,Placing an eq triangle
in the trisection of three balls:

The area covered

$= 3x(60/360)\pi R^2$ / $(sqroot(3)/4)x(2xR)^2$
= 0.90689968%

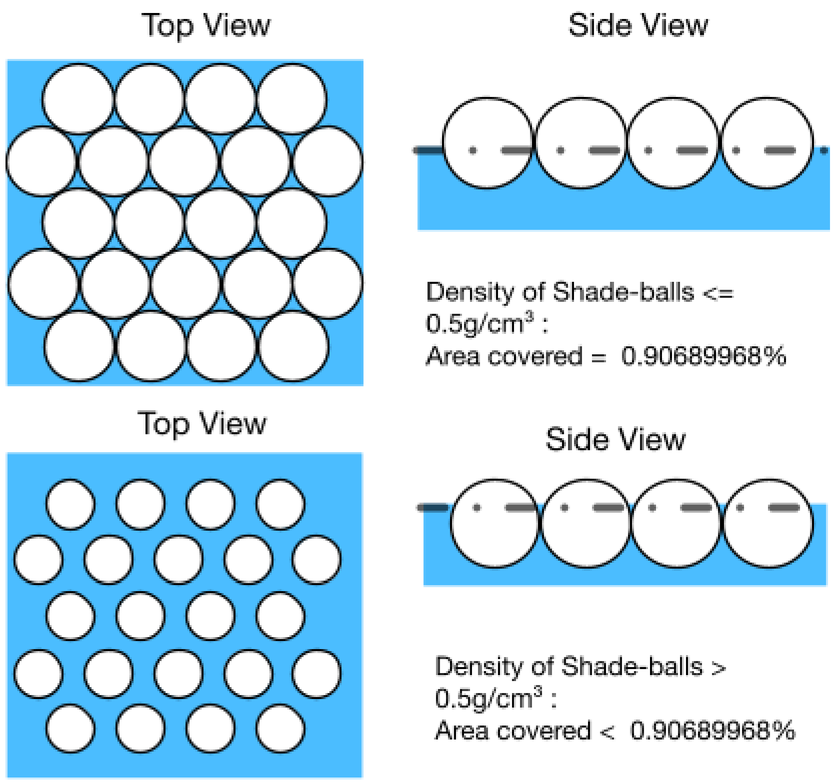


Fig 1.3

Now if the water level is above the half of the shade balls, the area covered is reduced to a great extent. So the density of the balls is required
to be less than half the density of water which is 1g/cm^3.
This will ensure that more than half of the shade balls remain above the level of water.

Now, this fact is to be noted that the shade balls need not to be too lighter
so as to prevent them to blew away during a thunder storm and block the roads etc.

Shade balls also help the balls to roll back to the reservoir if they are heavy. This also prevent the balls to layer up in the reservoir.

This is explained in the Fig. 1.2:
The force F is = Density x volume x g x Sin(30) / Cos(30).
This force helps the balls to spread up in the reservoir and is directly proportional to the density of the balls.

So the density is kept about 0.45g/cm³ .

The Material:

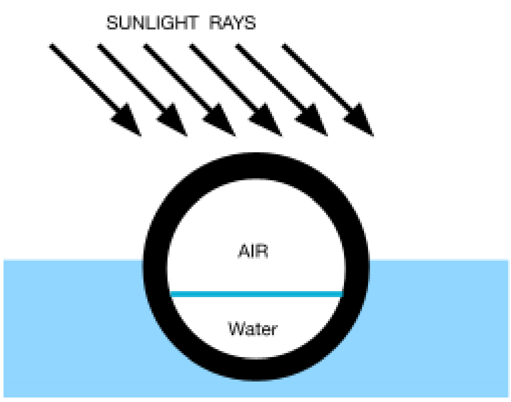
In order to keep the cost of the shade balls as low as possible they were decided to be made hollow from inside and can be filled with water to increase its weight. Water is a more suitable option as a liquid to be filled inside the shade balls as even if it leaks it still water. While deciding the material for the shade balls there were a lot of problems to be addressed for example:

- The material of the shade ball should not dissolve in water.
- The material of the shade ball should not deteriorate in water.
- The material of shade balls should not release any harmful substances in water.
- The material of shade ball should not deteriorate under sunlight for a long period of time as the air inside the shade ball acts as an insulator for heat.
- The pigment and outer covering of the ball should not dissolve or deteriorated in water and even if it did it should not effect the water's purity.
- The shade balls should be reusable or recyclables and should have a long shelf life to prevent frequent replacement.
- The material should be cheap as a lot of shade balls are required to cover up reservoirs.

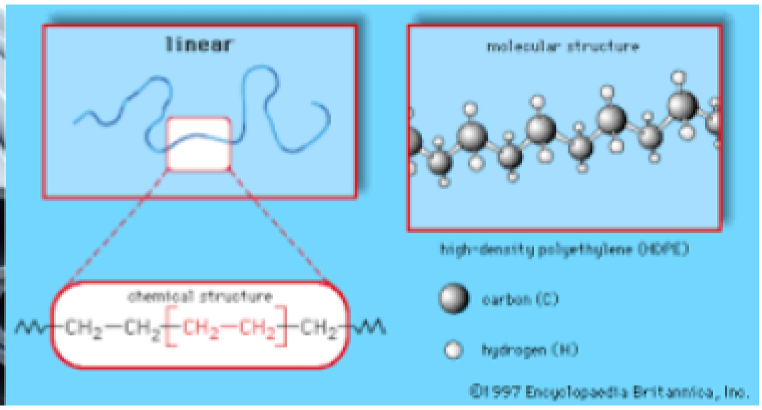
The material we choose is High-Density Polyethylene (HDPE) – Code 2
HDPE has a high strength-to-density ratio, meaning it is strong and lightweight. Additionally, it demonstrates resistance to mildew, mold, rot, and insects, as well as to corrosion, cracking, and weathering.

High density polyethylene is is the best material we found and addressed most of these issues, and the major fact is it is food grade plastic and you can chew it and it won't affect you.They are prominently used in making objects like milk jugs.

But the major issue with high density polyethylene plastic is that these plastics don't last long in sunlight and deteriorates over time which is a major disadvantage as a part of the shade balls will remain in sun for a long time.



This is a main issue because the of the sun rays falling on the upper surface of ball which is not in contact of water, this area is insulated due to air present inside of the ball and thus is heated to a relatively high temperature and can deteriorate easily. This makes the use of plastic challenging in this process.



But the solution was quite simple as carbon black can be mixed with the plastic and will increase the shelf life of this plastic making it safe to use for over 10 years and will not deteriorate in sunlight. This carbon black ok search two functionalities one is to strengthen the plastic and other is to provide pigment to the shade balls.

Dress material will not dissolve in water even if kept over 10 years in reservoir water with continuous exposure to sunlight so is completely fit for use as a shade ball.

Pigment: The pigment material was quite debatable in this project as the other food grade dies are not that stable in this environment so the carbon black fits in perfectly solving two of the major issues.

Size: The size of the shade ball is completely dependent on the use case of these balls and the reservoir. But it is required to keep them as big that they do not block the pipelines and major exit holes of the reservoir.
The standard size of the shade wall should be kept at a 100 mm, which serves best in the ease of manufacturing.

Manufacturing of the shade balls:

Our industries have been handling high density polyethylene for quite a long time and will not be a challenge for them to handle these materials fuse them with carbon black powder and form them into the shade balls.

The manufacturing can be done by first making the high density polythene material and then fusing it with the correct amount of carbon black. *This step is important so as to prevent any type of material getting shaved off of the ball (if the amount of carbon black powder is more) or reducing its shelf life (by having excess amounts of high density polyethylene). A balance is to be maintained between these two properties.* These things can be constructed down into two hemispherical parts by injection moulding of high density polyethylene at

high temperature and then combine them together to make the shade ball with a calculated amount of water inside the two hemispherical parts.
The amount of water sealed in the shade ball is dependent on the use case of the balls as in areas with light wind less amount of water can be added as the more part of shade ball is present outside the water surface the better their effectiveness is, in areas with high amount of winds and places near airports etcetera the ball can be more filled with water so as to you have more stability in Lew of some efficiency.

Why do we require shade balls?

Bromide (Br-) is natural occurring element associated with salt water. When water comes from high streams, it carries Br- with it. Bromide is harmless and almost impossible to remove completely. In the filter plant, when Bromide carrying water is treated with ozone (O3), it becomes Bromate (Br03 -), and it is carcinogenic.

When Bromate value was checked in filter plant, it was found less than maximum limit, i.e., 10 micrograms per litre (ug/l). But when value was checked in customer’s house, bromate value was found very high. So, it was found that Bromate value increased when water was stored in open reservoir before going to customer, Chlorine which is a disinfectant reacts with bromide in the presence of sunlight forms Bromate in large amount and even higher than ozone.

To prevent bromate formation, water surface was to be covered to stop the reaction of chlorine and bromide as it occurs in the presence of sunlight. In order to cover water surface, Shade balls were invented.

How Shade ball prevent degradation of water?

As discussed before the structure of shade balls, the black colour prevent light to reach surface and triggering the bromate reaction. Blocking sunlight also provides additional benefits. Other than stopping bromate formation. Addition chlorine was added to prevent algae formation which discolours the water to light green. But shade balls solved that problem too.
Evaporation takes place when sunlight heats up the upper layer of standing water, it forms vapours and then it is continuously carried away by breeze and replaces that moist air with dryer air hence increasing evaporation. This step occurs again and again and a lot of water is evaporated. But when water was covered with shade balls, it reduced the open surface area. Moreover, as we know that shade balls are half filled with water, they are not carried away by wind. Shade balls absorb heat in upper portion but remain cool in lower part which is in water reservoir as half of the balls are filled with air which act as thermal insulator and hence bottom half filled with water remains cool. So due to all of these reasons, shade balls reduce evaporation 80% to 90%
They act as a cover and prevent any waterfowl to go and get poisoned and also around airports so that water doesn’t get into engines. It was also found that they prevent birds from flying and sitting over reservoirs and hence water was saved from bird excreta.

Places in India where this technique can be applied

Shade balls mainly used for 2 reasons:
1. Stop water evaporation by covering most surface of water from sun.
2. Prevent formation of bromate(cancer-causing) in water.

According to a 2017 article, Hetwane Dam and Barwi dam (both in MH), averaged a water loss of 3.5cr L solely due to evaporation.

As per a test conducted in accordance with Indian meteorological standards, using shade balls lowered the evaporation loss of water by 80-85%

Now if we were to assume 80% of water(which would rather be evaporated) is saved, then we could help lakhs of people of Navi Mumbai by supplying an extra 70lakh L of water.

This is the case of Navi Mumbai, located near the sea, therefore most water is replenished by rain; but what about cities on interior parts of India, where rains are not as coastline areas.

The Department of Water Resources stated, "The annual potential evaporation ranges between 150 to 250 cm over most parts of the country. Monthly potential evaporation over the Peninsula increases from 15 cm in December to 40 cm in May. In the North-East, it varies from 6 cm in December to 20 cm in May. It rises to 40 cm in June in West Rajasthan."(source: https://mowr.gov.in)

Saurashtra(Gujarat) is another area where evaporation is fairly high (275-300 cm). The Deccan Plateauhas evaporation values ranging between 250-325 cm. These areas are prime examples of shade balls usage.

We were unable to find any data on bromate formation in lakes in India, as the Bureau of Indian Standards has "suggested" to refer to WHO's standard of <10µg/L bromate, and not enforced it strictly. Therefore people don't follow this guideline or do any Bromate tests whatsoever.

In all the places mentioned above, there is one common problem which can be solved using Shade Balls. Therefore it is evident that this technique can be applied all over the country. However its manufacture to transport cost depends a lot. Being the 7^{th} largest country by land in the world there is vast and extensive area to cover and hence proper logistics is required for transport as well as manufacture of shade balls.

Factory set ups is not a major issue as there are many existing factories through out the country which deal with the components require to make shade balls. Proper and efficient transport is required by railways or by road. Outsourcing this to many logistics and travel/ transport related companies would be the best option as they are experienced and have good tie ups for speedy and efficient work. Also, during this covid period it would be a boost to their industry too.

Economic and Biological Factors affecting Shade balls use in India

Shade balls can be used to cover lakes, reservoirs, swimming pools, fish culture tanks, and farm ponds using the floating cover method.
Shade balls are four-inch-diameter plastic balls manufactured of high-density polyethylene (HDPE). To prevent incoming UltraViolet light from sunlight, the balls are also covered with substances such as black carbon. UV rays are deflected by painting the balls black. Each ball costs 36 cents, which is approximately Rs.23 in Indian currency. These balls have a 25-year lifespan.

The shade balls aid in keeping the water's quality. Because the water includes bromide and chlorine ions, which react in sunshine to create bromide, a carcinogen, it must be kept in the shade. This reaction is prevented by the black carbon-coated balls. It also reduces algae growth in addition to halting evaporation. The balls are designed to float on water and operate as a protective barrier against dust, rain, and chemicals, as well as as bird repellents. It is the most cost-effective way of water conservation when compared to others.
There are also concerns about plastics leaching off balls, resulting in micro-plastic pollution, and some reports claim that black balls retain heat and provide greater surface area for bacteria to breed on.
By using shade balls as a floating cover, evaporation losses in an uncovered pan can be decreased by 80 to 85 percent. The use of shade balls can help to reduce algae growth. There were no negative impact on fish crops. When compared to alternative evaporation control approaches, this approach is more cost effective. It is suitable for use in farm ponds and reservoirs. The balls can be reused and are recyclable. Because the shade balls do not react with water, they have no effect on water quality. The cost of water treatment can be lowered to some amount by using this technology. The pH of the water in covered pits was determined to be suitable for drinking. In covered pits, total dissolved solids decreased, while dissolved oxygen was depleted due to a layer of balls on the water's top surface.

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 reasult.

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 reasult.

The shade balls are made of a type of plastic that requires a lot of water to make, as well as a lot of oil, natural gas, and energy. A total of 2.9 million cubic metres of water would be used to make 96 million balls with a standard thickness of 5mm. The balls are expected to have conserved 1.15 million cubic metres of water during their tenure on the reservoir.
The Imperial College, M.I.T., and the University of Twente study team estimates that the balls would need to be deployed for two and a half years before the water saved matched the water utilised.

This is in addition to other potentially harmful effects on the water, such as decreasing reservoir life or encouraging bacterial growth. Furthermore, the manufacture of the balls may have significant environmental consequences such as water contamination or carbon emissions.
Water management will become a major concern in the future decades as more high temperatures and droughts are projected as a result of climate change. Dr. Madani stated, " "We're not saying shade balls are harmful or shouldn't be used. We're only pointing out that the environmental cost of shade balls must be weighed against their benefits."

Conclusion

To conclude we would like to say that the problem statement was recognised and a possible solution was displayed theoretically. Implementing on a practical scale will give rise to more new challenges and hence we would like to work on it in a greater depth in the future. In this project work, we have not only discussed the pros of using shade balls, but also their cons and understanding them as well. Overall we have taken a wholesome approach and constructed our project work.