PHOSPHORUS BALANCE STUDY AT JAKKUR LAKE

Challenges to managing lake nutrient levels

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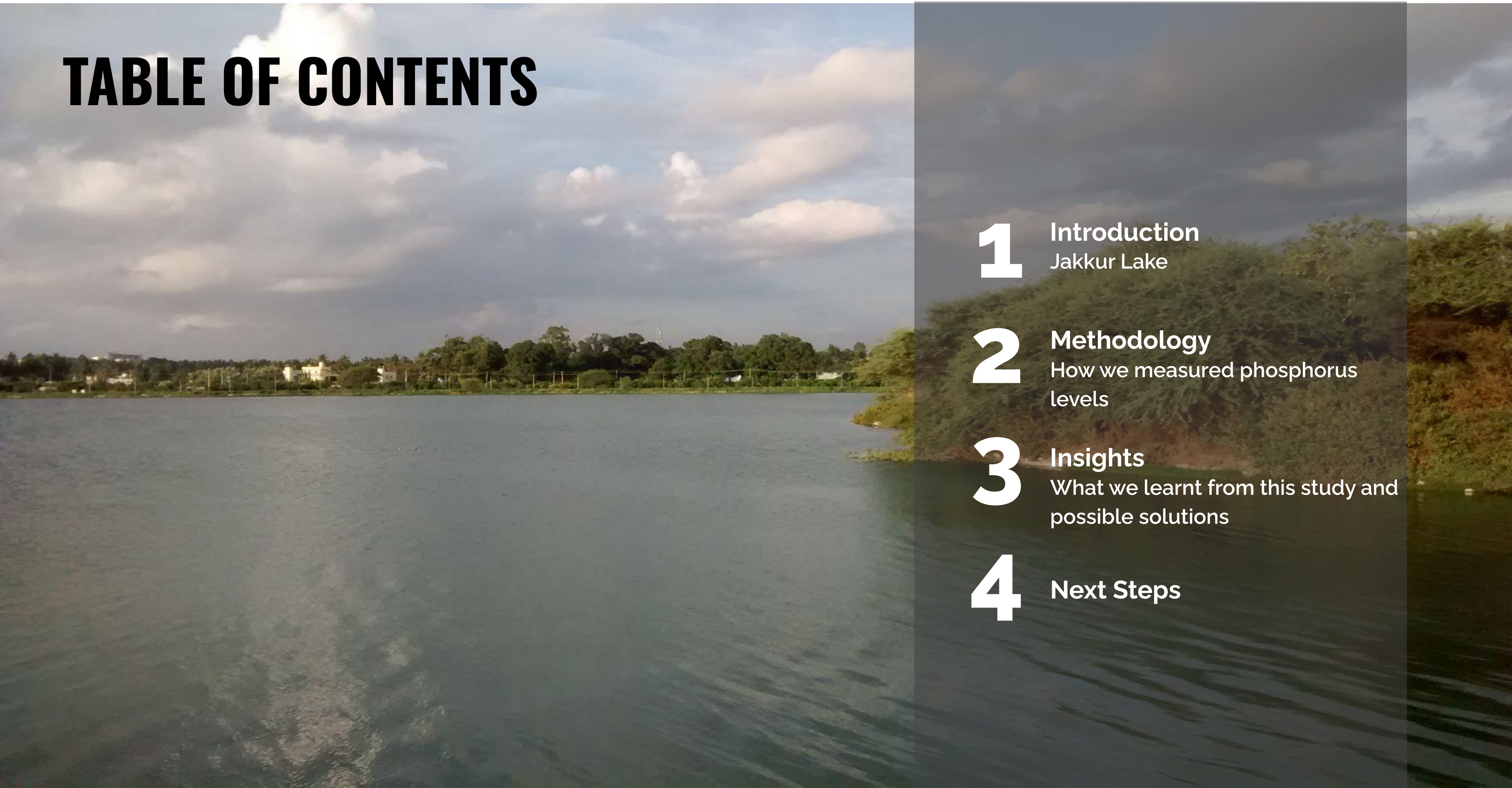
CSEI



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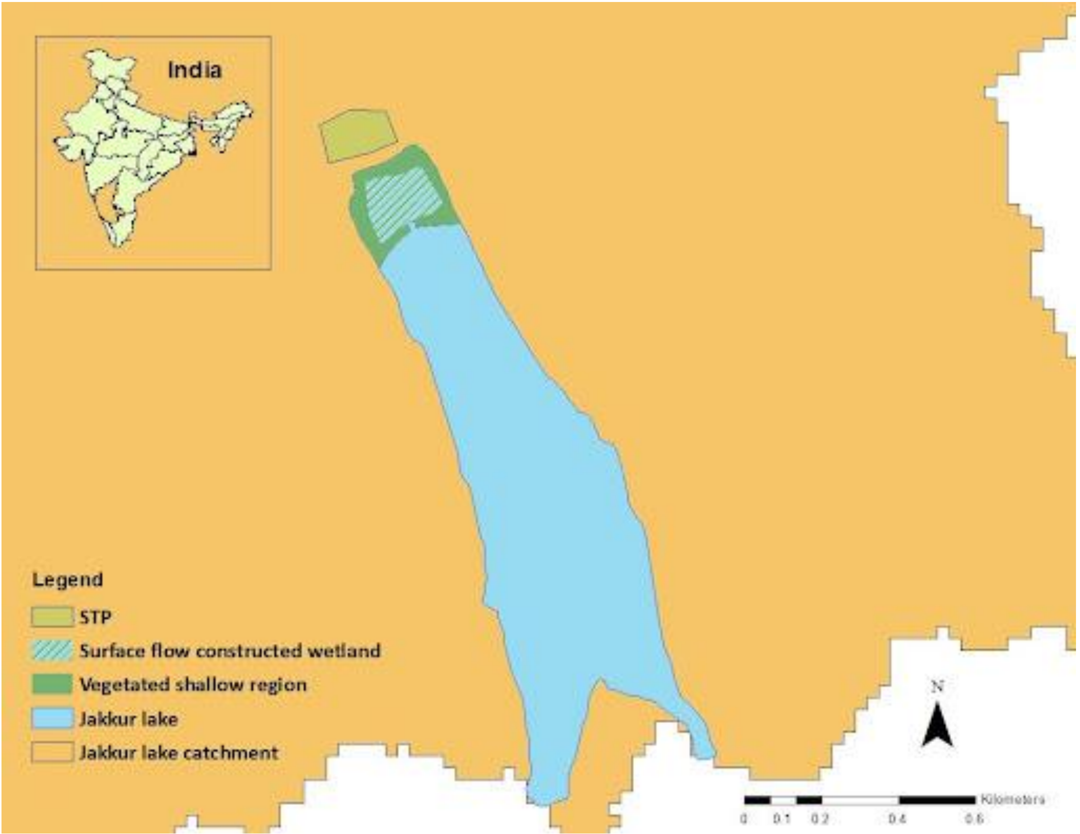
INTRODUCTION TO JAKKUR LAKE



Jakkur lake, a former irrigation tank, is a large water body in the northern part of Bengaluru with a surface area of 50 hectares and a capacity of 894 million litres (Jamwal, 2017). It is part of a cascading Yele Mallappa Chetty lake series with Yelahanka lake upstream and Rachenahalli lake downstream interconnected by stormwater drains. The water from this lake series finally drains into the Poniyar river.

Jakkur lake is perennial because it receives treated wastewater from a 15 MLD sewage treatment plant adjoining the lake.

It also has a constructed wetland that extends to about 5 hectares and further purifies the treated wastewater before it enters the lake (Figure 1).

Figure 1: Jakkur lake

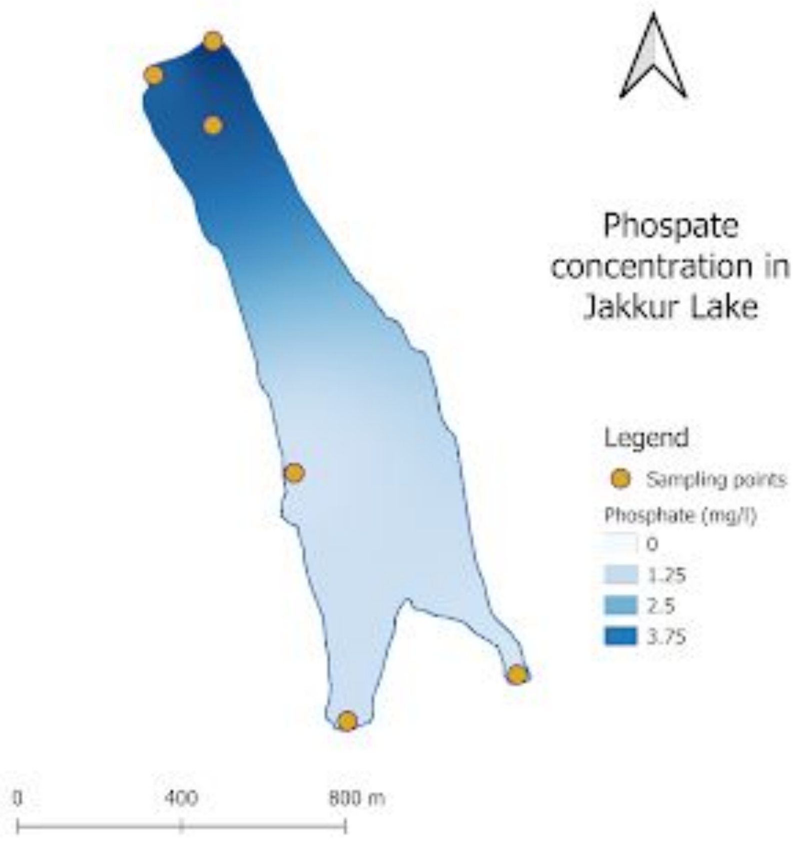
INTRODUCTION TO JAKKUR LAKE

Despite having an STP and a constructed wetland, Jakkur lake is still in a hypereutrophic state[1]. There are algal blooms and occasional fish deaths. To improve the lake's trophic status[2], it is important to understand the nutrient state of the lake. Therefore, we conducted a phosphorus balance study of the lake to understand the sources and sinks of phosphorus.

The phosphorus balance of Jakkur lake shows a huge ingress of external phosphorus into the lake.

[1] Lakes which are rich in nutrients (> 0.06 mg/L phosphorus) and have high productivity.
[2] A lake's trophic state is an indicator of the lake's nutrient content or the level of pollution. It also refers to the productivity of a lake, its ability to support plant and animal life.

METHODOLOGY



At the initial phase, water samples were collected on a monthly basis from 2019-2020 for quality analysis (phosphorus concentration). Samples were collected from the STP outlet, raw sewage inlet, constructed wetland outlet, lake observation deck and the two outlets of the lake, as shown in figure 2. Hydraulic flow rate at each sampling point was monitored once in 2020.

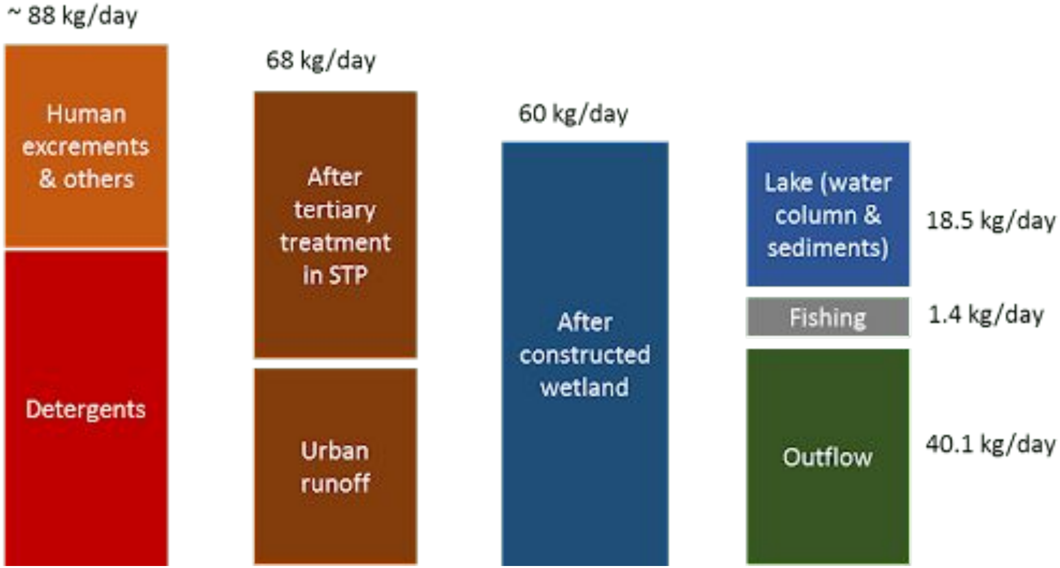
The phosphorus load at each sampling location was estimated from the flow and concentration data collected. Secondary data on the mass of phosphorus removed through fishing was also collected.

The phosphorus balance of the lake was created from these data.

Figure 2: Average phosphate concentration at different sampling points

WATER BALANCE OF JAKKUR LAKE

The constructed wetland at Jakkur discharges about 60 kg of phosphorus (P) into the lake daily. Out of this, about 18.5 kg of P is added to the lake sediment every day, while the rest is removed through the outflow and fishing (Figure 3). The phosphorus present in the lake is either in the dissolved form in the water column or in its condensed form in the sediments. The dissolved phosphorus in the water column results in the hypereutrophic state of the lake, which promotes excessive growth of macrophytes[3] and algae.



For the existing phosphorus balance in the lake, we examined various management options and their associated costs to improve the lake trophic status. Lake restoration is a slow process which requires a good understanding of physical, chemical and biological processes within the lake and the catchment. Lake nutrient management begins with efforts to reduce external nutrient loading.

Figure 3: Phosphorus balance of Jakkur lake

[3] Aquatic plants growing in or near water that are large enough to be visible to the naked eyes.

INSIGHTS & SOLUTIONS

This section provides insights derived from our study and the solutions we suggest.

INSIGHT 1:

External phosphorus load into Jakkur lake should be reduced at source

Despite having an STP at Jakkur, the lake still receives a significant amount of phosphorus through external loading. Nutrient management in lakes prioritise measures to remove/reduce external nutrient loading over in-lake measures. This is because the success of in-lake measures are limited and external nutrient reduction is often conducive to the maintenance of a stable lake environment. External phosphorus load into Jakkur lake should be reduced significantly at source. Detergents contribute about 65% of phosphorus load entering the lake while the remaining 35% is contributed by human excrements and other sources.

SOLUTION 1:

Regulation on use of detergents with phosphorus content

As a preventive approach, statutory regulation on phosphorus content in detergents and a mandate to use phosphorus-free detergents can reduce up to 65% phosphorus in the municipal sewage (Ramachandra *et al.*, 2017). This has to be a key component of a long-term preventive approach to managing lake nutrients. There are also other preventive approaches with lower time constraints.

INSIGHT 2:

Untreated wastewater is entering the lake

At Jakkur lake, not all the wastewater is treated before it enters the lake. An untreated urban runoff channel that directly enters the constructed wetland contributes 37 kg of phosphorus per day.

SOLUTION 2:

Divert wastewater stream into the STP and upgrade the STP

This wastewater stream can be prioritised and addressed by diverting it into the STP. Technology upgradation of the STP to incorporate the enhanced biological phosphorus removal (EPBR) process that can significantly reduce phosphorus concentration is also necessary.

Prior studies indicate that EPBR is expected to remove 86-99% phosphorus from wastewater (Lesjean *et al.*, 2003; Ong *et al.*, 2016; Pacheco and Roberto, 2018; Izadi, Izadi and Eldyasti, 2020).

Even with a conservative assumption of 86% phosphorus removal by the STP with additional EPBR process, the phosphorus load entering the constructed wetland can be reduced to 17.5 kg/day.

INSIGHT 3:

Constructed wetland at Jakkur lake is not performing optimally.

At present, the constructed wetland area of Jakkur lake consists of macrophytes and an algal pond. The constructed wetland removes only about 12% of the phosphorus entering the system. The performance of the constructed wetland has declined due to raw sewage inflow and overloading in terms of hydraulic and phosphorus load.

SOLUTION 3:

Increase plant cover in the constructed wetland for better nutrient management

With the STP treatment of the sewage in urban runoff, the quality of inflows into the constructed wetland can be improved and the performance of the constructed wetland system can be expected to improve slowly with time. The phosphorus retention in the constructed wetland can be further enhanced by increasing its plant cover. One way to achieve this is through the installation of floating treatment wetlands (FTWs) in about 50% of constructed wetland surface area. Field studies indicate phosphorus removal rate by FTWs to be in the range 0.4 to 1.1 g[4]/day/m^2.

Through this, the phosphorus retention by the constructed wetland - FTW system can improve (from 12% to 65%) and can reduce the phosphorus loading into the lake to 6.2 kg/day. This significantly reduces the external loading of phosphorus into the lake.

[4] According to Floating Island International field studies (https://midwestfloatingisland.com/research/)

INSIGHT 4:

Managing phosphorus in the lake needs a good financial model

Managing phosphorus to control lake eutrophication involves significant technology investments as well as operation and maintenance (O&M) costs that need a good financial model. For Jakkur lake, the capital cost for phosphorus management includes the cost for scaling up and upgradation of STPs to incorporate diverted urban runoffs, installation of FTWs and desilting. STP upscaling and upgradation costs approximately Rs 16.9 crore with an additional O&M cost of Rs 7.8 crores/year[5]. Installation of FTWs will approximately cost Rs 110.6 crores with additional O&M cost of Rs 3.9 crores/year. Desilting of Jakkur lake will cost about Rs 1.6 to 3.4 crores[6].

SOLUTION 4:

Aligning incentives through lakes restoration

We need to develop models for financing and managing lake nutrients. In addition to ecological services, lake restoration also provides livelihoods for local communities that assist lake maintenance. For instance, farmers have been using the fodder collected from the lakes as livestock feed, selling the bundles each weighing about 30-40 kg for Rs. 150-200 (*The Hindu*, 2011; Mehrotra, 2019). Organisations like Janastu have also been training communities to use the fiber from plants harvested from constructed wetlands to make craft products and use them as a source of income (Biome Trust, 2018). The sludge from STP after proper treatment is sold as manure for agricultural application. Also, fishing activities in Bengaluru's lakes brings some income to the community. Fishermen at Jakkur lake catch about 40-100 kg of fish in lakes every day and sell it for a price range of about Rs. 130-400/Kg.

[5] Approximate cost was estimated from the sources; Advance Methods for Treatment of Textile Industry Effluents, STP Technologies Technologies & Their Cost Effectiveness | Cost effectiveness of phosphorus removal
[6] Estimated from the sources; Chennai to have more restored water bodies this year, Development of Lake Conservation Projects

NEXT STEPS

NEXT STEPS IN NUTRIENT MANAGEMENT

Nutrient management needs a cycle of implementing and ***testing the response*** of phosphorus concentration to in-lake measures such as floating treatment wetlands.

In-lake measures need to be introduced, if necessary, as the next stage of nutrient management once the external nutrient inputs are reduced. This needs to be carried out after detailed evaluation of phosphorus removal by external measures. For secondary contact recreation, the lake phosphorus concentration should be below 0.08 mg/L. With an outflow of 1.4 kg/day of phosphorus and removal of about 1.4 kg/day of phosphorus through fisheries, the residual phosphorus of 4.8 kg/day would need in-lake treatment measures.

One possible approach is the installation of FTWs in the lake to balance the daily phosphorus loading into the lake. For the estimated external loading, FTWs covering a surface area of 1.5 % of the lake may be required (Figure 4).

Further, to prevent the internal loading of phosphorus from the lake sediments, desilting of the lake sediments can be adopted. However, desilting is difficult in Bengaluru's lakes because they are perennial. Moreover, desilting disturbs the lake biodiversity and lake functions.

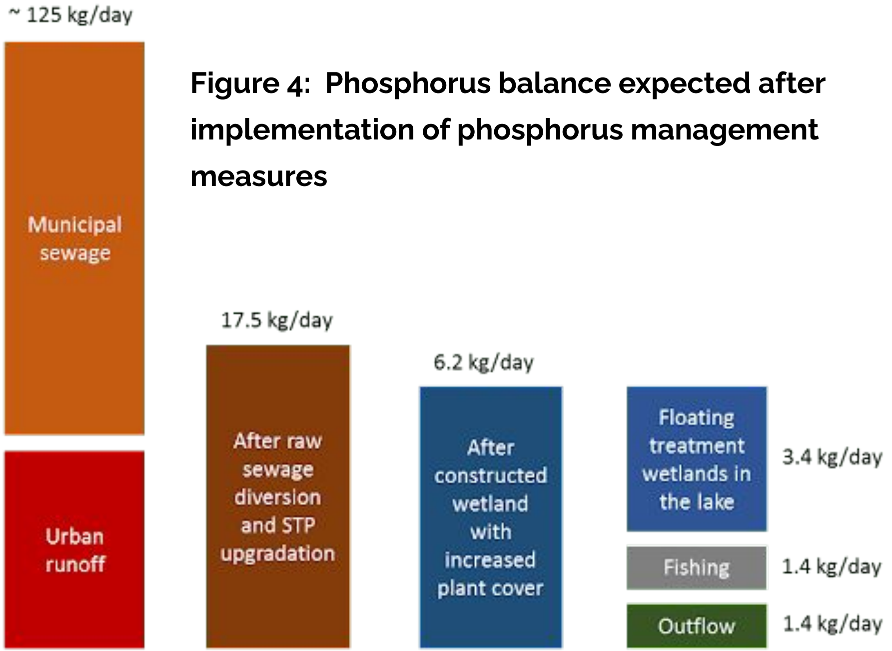


Figure 4: Phosphorus balance expected after implementation of phosphorus management measures

WAY FORWARD

The phosphorus management measures discussed are not to be carried out simultaneously but step-wise with careful assessment on improvement with each measure. The necessity of each measure is dictated by the performance of the preceding measure adopted.

While these activities do not bring income to fund maintenance of the lake, they do reduce the costs of its maintenance. They also create incentives for local people to act as guardians working to sustain and protect the health of the lake.

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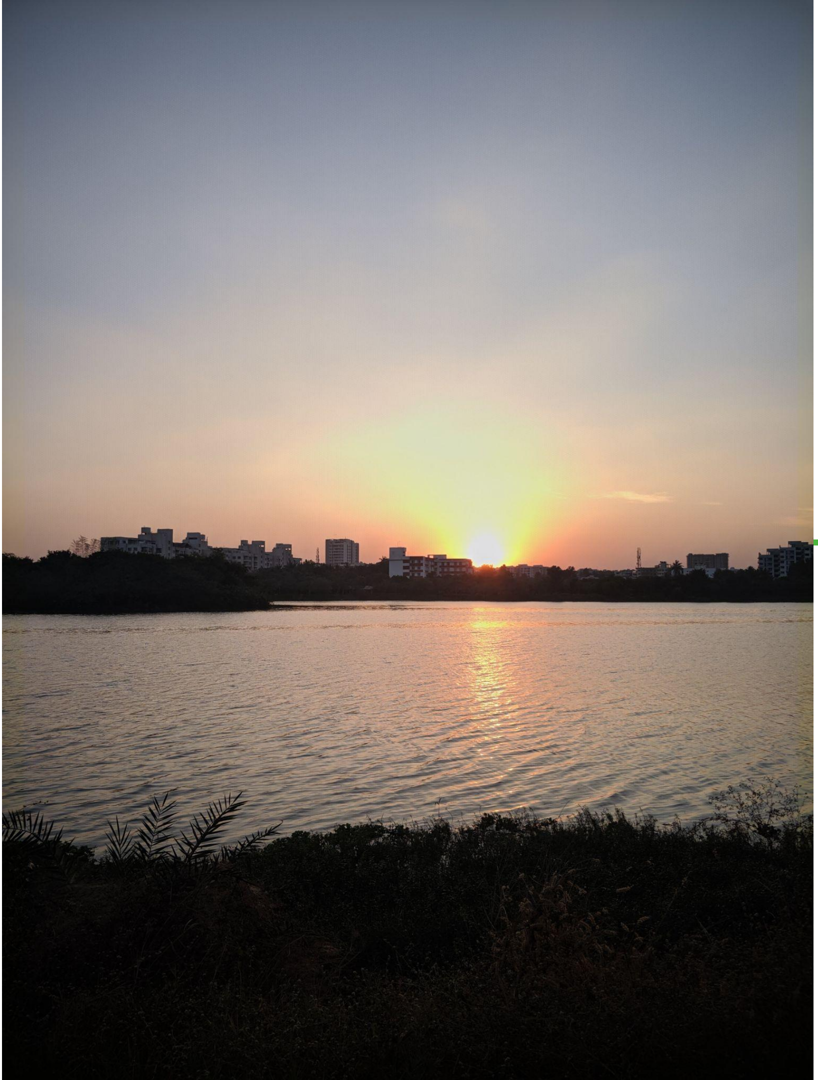

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