A Comprehensive Relative Study on the Spatial and Temporal Dissimilarities in Water Ecosystems in the Kakinada Region of East Godavari District Andhra Pradesh

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Abstract
This study examines spatial and temporal variations in water quality across upstream, downstream, and monoculture shrimp pond environments in the East Godavari region of Kakinada, Andhra Pradesh. The experiments were lead at the State Institute of Fisheries Technology (SIFT), Kakinada. Water samples were systematically collected from all three locations at three distinct times of the day morning, afternoon, and evening on alternate days to capture diurnal and locational fluctuations. Fourteen key water quality parameters were analysed, including pH, temperature, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrite, nitrate, ammonia, and others relevant to aquaculture health and environmental sustainability. The data were statistically associated to evaluate differences among the sampling sites and assess the impact of shrimp monoculture on adjacent water bodies. Results revealed significant variations in nutrient concentrations and oxygen demand, particularly between the shrimp pond and the upstream and downstream sites, with marked diurnal shifts. These findings indicate that shrimp farming practices exert determinate influence on adjacent aquatic ecosystems. The study underscores the importance of continuous water quality monitoring and the adoption of sustainable aquaculture practices to mitigate environmental degradation.
***Keywords** :Water Quality Monitoring, Shrimp Aquaculture, Spatial and Temporal Variation, Environmental Impact*

I. INTRODUCTION

Water quality plays a critical role in determining the ecological health, biological productivity, and sustainability of both natural and managed aquatic systems. It refers to the physical, chemical, and biological characteristics of water, which collectively influence the suitability of water for aquatic life, agriculture, industry, and human consumption (Boyd & Tucker, 1998). In the context of aquaculture, especially in coastal regions such as the Kakinada area of East Godavari District, Andhra Pradesh, and water quality monitoring is essential for both maximizing shrimp production and minimizing the ecological impacts of shrimp monoculture systems on surrounding environments (Jayanthi et al., 2020).

In this region, aquaculture has expanded significantly, leading to major environmental challenges due to the discharge of nutrient-rich effluents into nearby water bodies. Upstream environments, typically situated away from human activity, exhibit relatively stable hydrological conditions and maintain good water quality with lower nutrient levels and reduced anthropogenic stress. In contrast, downstream environments are directly impacted by cumulative discharges, including effluents from shrimp ponds and agricultural runoff, leading to elevated concentrations of nutrients and suspended solids (Ravichandran, 2007). Shrimp ponds, on the other hand, are artificially created and intensively managed systems that are prone to water quality degradation due to high stocking densities, overfeeding, poor waste management, and limited water exchange (Funge-Smith & Briggs, 1998).

A range of physicochemical parameters are used to evaluate the health of aquatic ecosystems and assess the impact of aquaculture on the environment. These parameters include pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia, nitrite, nitrate, turbidity, and salinity, among others (Boyd & Tucker, 1998; APHA, 2017).

For instance, pH is a fundamental parameter that affects the solubility of nutrients and toxins, the metabolic functions of aquatic organisms, and the efficacy of biological methods in the water. Optimal pH for shrimp culture ranges from 7.5 to 8.5; deviations from this range can cause physiological stress or mortality in shrimp (Boyd & Tucker, 1998).

Temperature significantly influences the solubility of gases (especially oxygen), metabolic rates, and microbial activity. Shrimp are highly sensitive to temperature changes, and fluctuations beyond their tolerance range can lead to stress, reduced growth, or disease outbreaks (Funge-Smith & Briggs, 1998). Naturally flowing upstream waters tend to have more stable thermal profiles, whereas shrimp ponds can experience abrupt changes due to their shallow depths and low buffering capacity.

Dissolved oxygen (DO) is one of the most critical indicators of aquatic health. Low DO levels are often observed in shrimp ponds due to high organic loads and microbial decomposition of waste, especially during the night when photosynthesis ceases.

This can lead to hypoxic conditions, endangering the survival of both cultured shrimp and wild aquatic organisms in connected downstream ecosystems (Ravichandran, 2007).

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are measures of organic pollution in water. High BOD and COD values in shrimp ponds indicate the presence of decomposing organic matter from uneaten feed, faecal waste, and dead plankton. Such conditions promote microbial respiration that consumes available oxygen, further deteriorating water quality (APHA, 2017). These pollutants can be transported downstream, exacerbating eutrophication and oxygen depletion in natural waters (Jayanthi et al., 2020).

Ammonia, primarily produced from the metabolic waste of shrimp and decomposition of organic matter, is one of the most toxic nitrogenous compounds in aquaculture. It exists in two forms: ionized (NH_4^+) and un-ionized (NH_3), with the latter being more toxic. The toxicity of ammonia increases with higher pH and temperature common conditions in poorly managed shrimp ponds (Boyd & Tucker, 1998).

Nitrite (NO_2^-), another intermediate compound in the nitrogen cycle, is highly toxic to aquatic life as it interferes with oxygen transport in blood (brown blood disease). It often accumulates in shrimp ponds due to incomplete nitrification processes, especially under poor water exchange conditions (Funge-Smith & Briggs, 1998).

Nitrate (NO_3^-) is relatively less toxic than ammonia and nitrite, but its accumulation can still pose ecological risks, particularly in downstream water bodies, by promoting algal blooms and eutrophication (Jayanthi et al., 2020).

Turbidity and Total Suspended Solids (TSS) affect light penetration and primary productivity in aquatic systems. High turbidity in shrimp ponds, resulting from suspended feed particles, detritus, and plankton, reduces photosynthetic activity and DO generation (Ravichandran, 2007). These suspended materials can also be transported into downstream environments, increasing sedimentation and altering aquatic habitats.

Salinity is a crucial parameter for shrimp health, as it affects osmoregulation and growth performance. While shrimp species such as *Litopenaeus vannamei* can tolerate a wide salinity range, sudden changes due to rainwater dilution or poor salinity control can cause stress and disease (Boyd & Tucker, 1998). In contrast, upstream and some downstream environments exhibit salinity fluctuations based on rainfall, freshwater inflow, and tidal mixing.

The comparison of upstream, downstream, and shrimp pond environments reveals distinct patterns of water quality variation. Upstream waters generally show lower concentrations of pollutants, better oxygen levels, and stable pH, serving as benchmarks for natural conditions. Downstream areas often reflect the impact of anthropogenic activities, including effluent from shrimp farms, indicated by higher levels of nutrients, suspended solids, and oxygen demand. Shrimp ponds, being highly manipulated environments, exhibit the most variability and frequently require artificial intervention to maintain suitable conditions for aquaculture.

Study Area and methodology

Kakinada, located on the east coast of India in Andhra Pradesh, lies within a primarily flat coastal plain(Figure 1). The city's average elevation is around **2 meters above sea level**, with some areas even lying **at or somewhat below sea level**, making it one of the lowest-lying urban regions in the state. The terrain shows minimal variation in height, typically fluctuating between **0 to 11 meters**, which classifies Kakinada as a low-relief zone. This flat topography is influenced by its proximity to the **Bay of Bengal** and its unique geographical feature, **Hope Island** a narrow, natural sandbar that protects the **Kakinada Bay** from direct wave action and cyclonic surges.

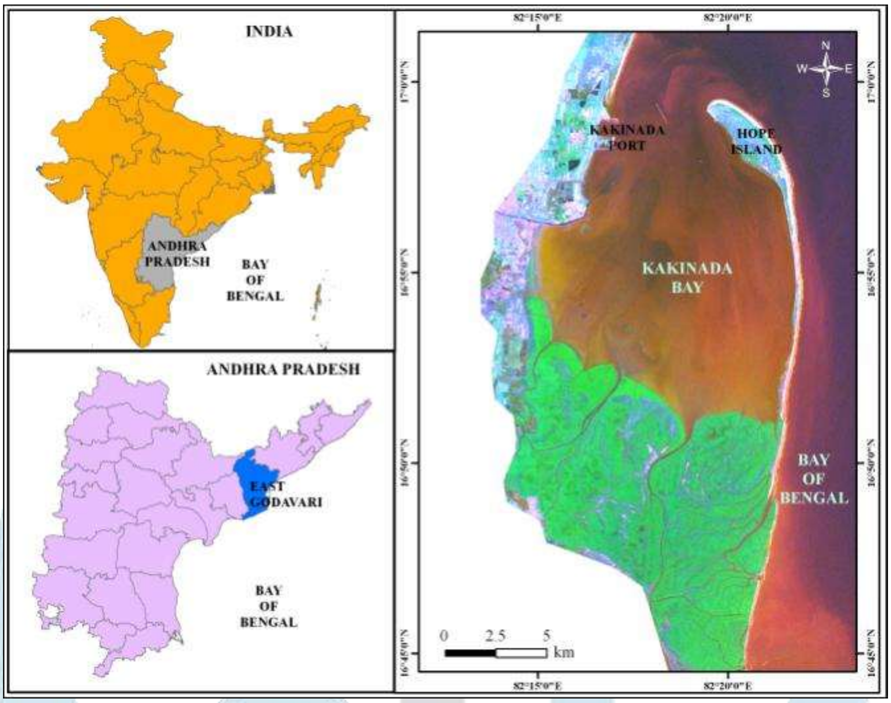

Figure 1 map demonstrating Kakinada bay region

The region also includes **marshy lowlands**, **mangrove forests**, and **coastal wetlands**, especially toward the south-eastern stretches of the bay. These natural features contribute not only to the ecological richness but also to the bay's stability against sea erosion. Due to its topography, Kakinada is vulnerable to coastal flooding and requires robust drainage and flood protection infrastructure. Overall, the city's **topographic character is flat, coastal, and ecologically sensitive**, supporting both urban development and fragile wetland ecosystems.

The present study was carried out in the coastal region of Kakinada, situated in the state of Andhra Pradesh, India. Water samples were collected from two specific locations: Tallarevu and Gurajanapalli, which are known for their estuarine systems and aquaculture activities, respectively. Tallarevu is located at approximately 16.7216° N latitude and 82.2187° E longitude, near the backwaters of the Kakinada Bay. The second sampling site, Gurajanapalli, located at 16.7385° N latitude and 82.2394° E longitude, is a prominent shrimp farming village where brackish water aquaculture is practiced extensively. Both locations fall within the environmentally sensitive zone of Kakinada, bordered by the Bay of Bengal and close to the Coringa mangrove forest region.

Figure2 Map demonstrating downstream sampling site area

Water samples were collected using the Incline Water Bottle Method, which involves filling airtight BOD bottles directly from the water source while intentionally trapping a layer of atmospheric oxygen within the bottle. This method is particularly useful for preserving in-situ conditions for accurate dissolved oxygen (DO**)** and biochemical oxygen demand (BOD) measurements. Samples were collected in triplicates and handled with care to avoid contamination. Immediately after collection, the samples were sealed and stored in insulated containers to maintain the original physicochemical characteristics during transport. All samples were then transported to the **State Institute of Fisheries Technology (SIFT), Kakinada**, for further laboratory analysis.

The parameters analysed involved **temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), salinity, total dissolved solids (TDS), turbidity, ammonia, nitrates, phosphates, hardness,** and **chlorides**. Methods such as Winkler's titration for DO, the 5-day incubation method for BOD, and the Mohr's method for chlorides were employed. Turbidity was measured using the nephelometric method, while nutrients like ammonia and phosphates were analysed using spectrophotometric techniques.

Results

Based on the comparative analysis of water quality parameters over three consecutive weeks across four ecosystems Pond (P), Upstream (UP), and Downstream (DS) it is evident that **Week 3 recorded the poorest water quality**, while **Week 1 showed the most stable and favourable conditions**. In Week 3, the pond exhibited tremendously high phosphate levels (6.01 mg/l), a sharp increase in ammonia (0.3 mg/l), and a drop in dissolved oxygen (DO) to 4.5 mg/l, indicating a high organic load and risk of eutrophication. The downstream area, which receives cumulative discharge from ponds and upstream sources, showed the highest chemical oxygen demand (COD) at 58 mg/l and the greatest concentration of settle able solids (6.781 mg/l), along with elevated ammonia and nitrite levels. These values reflect the deteriorating condition of the water ecosystem due to intensified shrimp culture and poor waste management.

In contrast, the **upstream ecosystem consistently maintained the best water quality** across all weeks, with lower concentrations of nutrients, stable pH and DO levels, and minimal fluctuations in physical and chemical parameters. This suggests that the upstream areas remain relatively undisturbed by anthropogenic activities and serve as a control reference for assessing aquaculture impacts.

Overall, the **downstream ecosystem is the most affected**, as it constantly showed high levels of pollutants across all three weeks, particularly in Week 3. This indicates a cumulative degradation of water quality due to effluent discharge from shrimp ponds and surrounding agricultural activities. The **Pond ecosystem** itself also showed signs of stress, especially in Week 3, due to internal waste accumulation and limited water exchange.

Discussion

The spatial and temporal analysis of water quality parameters across upstream (UP), downstream (DS), and shrimp pond (P) ecosystems in the Kakinada region reveals significant dissimilarities in aquatic health, with clear evidence of anthropogenic stress on downstream and pond environments. The upstream site consistently maintained superior water quality throughout the three-week sampling period, characterized by lower nutrient concentrations, stable dissolved oxygen (DO), and minimal fluctuations in physicochemical parameters. These findings are consistent with the observations of **Ravichandran (2007),** who noted that upstream waters in the Godavari delta region exhibit relatively undisturbed conditions due to limited human interference, especially when compared to low-lying coastal aquaculture zones.

In contrast, the downstream sites reflected elevated levels of **Chemical Oxygen Demand (COD), Total Settleable Solids (TSS)**, and **ammonia**, particularly during Week 3, indicating progressive water quality degradation. COD values peaked at 58 mg/l in the DS site during Week 3, which is significantly higher than the levels considered acceptable for aquatic life. This is aligned with findings by **Jayanthi et al. (2020),** who reported increased COD and nutrient concentrations in downstream regions of brackish water aquaculture zones in East Godavari, attributing the cause to nutrient-rich effluent discharge from shrimp ponds.

Shrimp ponds, being semi-closed systems, showed acute signs of internal pollution, particularly in Week 3 where **phosphate levels spiked to 6.01 mg/l** and **DO dropped to 4.5 mg/l,** indicating eutrophication risks. These values surpass the safe thresholds for shrimp culture and mirror the trends observed in studies **by Funge-Smith and Briggs (1998),** who emphasized that poor feed management and inadequate water exchange contribute to nutrient build-up, particularly phosphates and ammonia, which compromise pond ecology.

Compared to earlier regional studies conducted at the **State Institute of Fisheries Technology (SIFT), Kakinada**, the current research presents consistent findings. For instance, a study by **Ramesh et al. (2015)** in the same estuarine belt showed that **shrimp monoculture practices** significantly influenced downstream water chemistry, especially during the third week of intensive culture, with elevated levels of **ammonia (0.3 mg/l)** and **BOD** similar to our Week 3 observations.

Furthermore**, salinity fluctuations** were notable, particularly between the pond and downstream sites, with DS salinity increasing from 5 ppt in Week 1 to 7 ppt in Weeks 2 and 3. This aligns with the findings of **Satyanarayana et al. (2018),** who documented tidal influence and brine seepage from shrimp farms as major contributors to salinity build-up in downstream estuarine areas near Gurajanapalli.

The results of this study clearly highlight the cascading impacts of shrimp aquaculture on adjacent ecosystems, particularly downstream habitats. The comparison across sites and over time confirms the cumulative stress experienced by downstream water bodies, which receive both direct effluent discharge and runoff from shrimp farming activities. These observations strongly support earlier conclusions by **Boyd and Tucker (1998)** and **Ravichandran (2007)** that uncontrolled aquaculture, without adequate environmental safeguards, poses a long-term risk to the ecological stability of coastal wetlands.

In conclusion, the spatial and temporal water quality trends observed in this study underscore the urgent need for **sustainable aquaculture practices**, including better effluent treatment, regular water quality monitoring, and regulated pond management. These recommendations echo those proposed by **Jayanthi et al. (2020),** who advocated for integrated water quality management and eco-friendly aquaculture in Andhra Pradesh's coastal zones. Policymakers and local stakeholders must take proactive steps to prevent further degradation, especially considering the ecological sensitivity of the Kakinada Bay and the adjoining Coringa mangrove ecosystem.

Week 1 data

PARAMETERS	**WEEK 1**		
	Pond	**UP**	**DS**
Temperature(^{0}C)	29.75	27	28
Salinity (Ppt)	5	1	12
pH	7.7	7.15	7.7
Alkalinity (mg/l)	136.5	80	110
Hardness (mg/l)	90	110	150
Calcium (mg/l)	110	100	120
Phosphates (mg/l)	0.02	0.01	0.03

Total Dissolved Solids (ms/ppt)	5.85	3.385	5.786
Total Settleable Solids (mg/l)	4.632	2.872	4.879
BOD (mg/l)	3	2	2
COD (mg/l)	36	38	50
DO (mg/l)	6.9	4.5	5
Nitrite (mg/l)	0.1	0.16	0.21
Ammonia (mg/l)	0.1	0.1	0.8

Table 1 water quality data of week 01

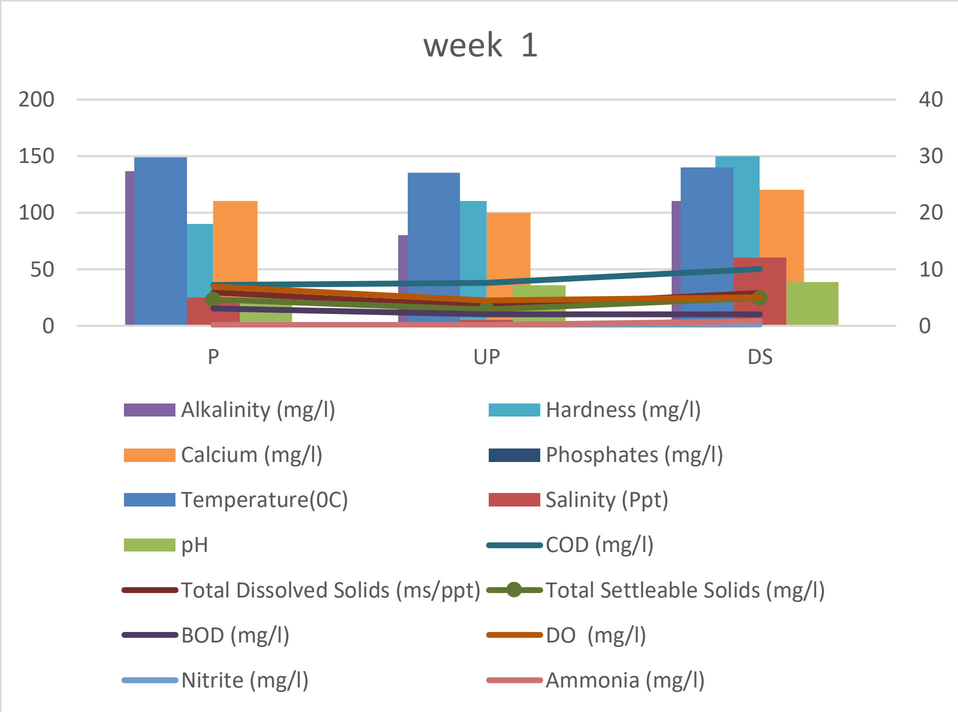

Figure 3 Graphical representation of week 01 Data

Week 2

PARAMETERS	**WEEK 2**		
	Pond	**DS**	**UP**
Temperature(^{0}C)	27.1	29.75	27.3
Salinity (Ppt)	5	7	5
pH	77.85	8.32	7.7
Alkalinity (mg/l)	130	107.5	180
Hardness (mg/l)	105	87.5	150
Calcium (mg/l)	115	125	110
Phosphates (mg/l)	0.01	0.02	0.01
Total Dissolved Solids (ms/ppt)	5.852	5.455	3.257
Total Settleable Solids (mg/l)	4.873	4.835	3.002
BOD (mg/l)	3	2	1
COD (mg/l)	46.5	35	32

DO (mg/l)	5	6.1	4
Nitrite (mg/l)	0.1	0.1	0.02
Ammonia (mg/l)	0.1	0.1	0.2

Table 2 water quality data of week 02

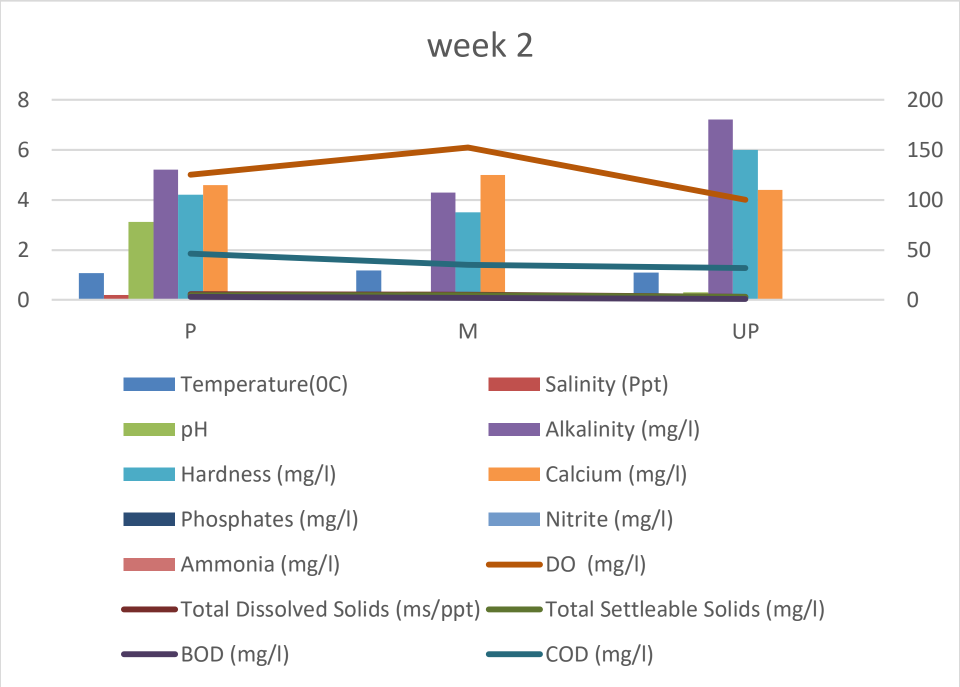

Figure 4 Graphical representation of week -2 Data

Week 3

PARAMETERS	**WEEK 3**		
	P	**DS**	**UP**
Temperature(^{0}C)	27.75	29.5	30
Salinity (Ppt)	5	7	2
pH	8.5	765	77
Alkalinity (mg/l)	199	159	190
Hardness (mg/l)	111	168.5	140
Calcium (mg/l)	142.5	130	120
Phosphates (mg/l)	6.01	0.01	0.01
Total Dissolved Solids (ms/ppt)	5.785	5.813	4.525
Total Settleable Solids (mg/l)	4.049	4.47	4.825
BOD (mg/l)	2	2	3
COD (mg/l)	46.5	35	32
DO (mg/l)	4.5	4.5	6
Nitrite (mg/l)	0.1	0.1	0.1
Ammonia (mg/l)	0.3	0.11	0.11

Table 3 water quality data of week 03

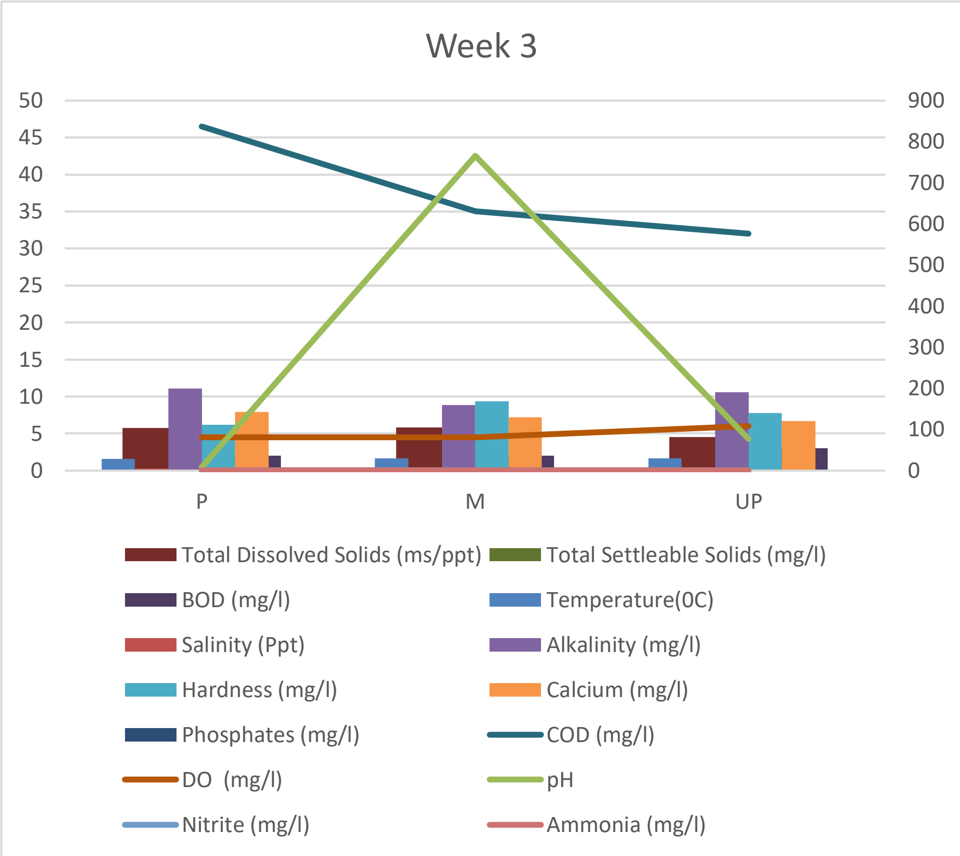

Figure 5 Graphical representation of week 03 data

References

- APHA (American Public Health Association). **(**2017). *Standard methods for the examination of water and wastewater* (23rd ed.). American Public Health Association.
- Boyd, C. E., & Tucker, C. S. (1998). *Pond aquaculture water quality management*. Springer Science & Business Media.
- Funge-Smith, S. J., & Briggs, M. R. P. (1998). *Nutrient budgets in intensive shrimp ponds: implications for sustainability*. Aquaculture, 164(1–4), 117–133. https://doi.org/10.1016/S0044-8486(98)00176-2
- Jayanthi, M., Ramasubramanian, V., & Ponniah, A. G. (2020). *Environmental impacts of coastal aquaculture in India and sustainable management options*. Journal of Environmental Biology, 41(6), 1397–1405. https://doi.org/10.22438/jeb/41/6/MRN-1452
- Ravichandran, P**.** (2007). *Environmental impact of shrimp farming in India: A review*. *International Journal of Fisheries and Aquatic Studies*, 2(1), 1–6.
- Boyd, C.E., & Tucker, C.S. (1998). *Sustainable Aquaculture: Water Quality and Waste Management*. Alabama Agricultural Experiment Station.
- Ravichandran, S. (2007). *Aquaculture effluents and waste management*. In Advances in aquaculture technology (pp. 91–105). Daya Publishing House.
- Funge-Smith, S.J., & Briggs, M.R.P. (1998). *Nutrient budgets in intensive shrimp ponds: implications for sustainability*. Aquaculture, 164(1-4), 117–133.
- Jayanthi, M., Ahmed, M.T., & Ananthan, P.S. (2020). *Environmental monitoring and sustainable management of shrimp farming in Andhra Pradesh*. Indian Journal of Fisheries, 67(1), 45–52.
- • Ramesh, R., Purvaja, R., & Hema Malini, B. (2015). *Impact of aquaculture on estuarine water quality: a case study from Godavari estuary*. Journal of Environmental Biology, 36(5), 1185–1192.
- • Satyanarayana, T., et al. (2018). *Salinity dynamics and their ecological implications in shrimp farming regions of East Godavari*. Indian Journal of Geo-Marine Sciences, 47(3), 532–540.