HS5.12
EGU22-57

Process modification and low-cost intervention of an old sewage treatment plant to improve biological nutrient removal

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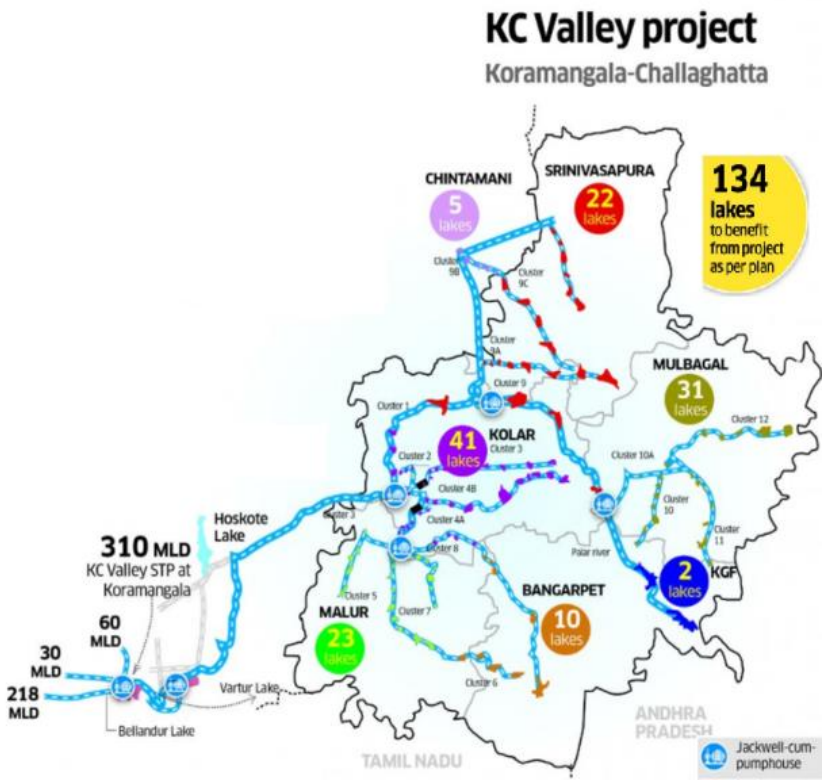
Introduction

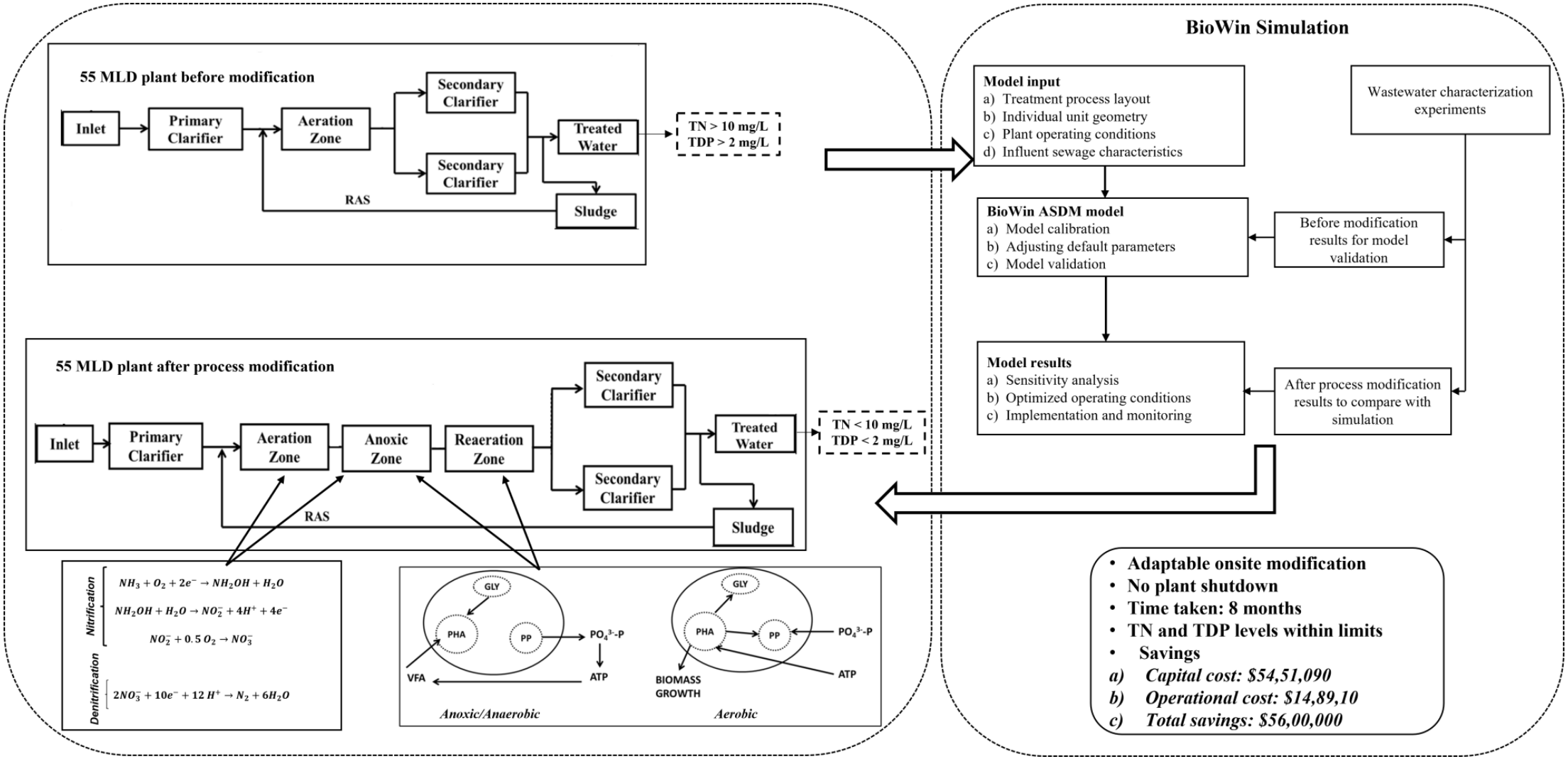
- Treated water - STP - generally discharged into - nearby flowing surface water body
- Water improves its quality through natural processes before it is picked up by another city downstream
- Urbanization - growth of cities - reducing distance treated water travels between adjacent cities
- Authorities - continuously **revise - discharge standards** - **STPs to be constantly upgraded**
- Up-gradation - **process modifications** /retrofitting with modern machinery
- Retrofitting - expensive -time and resources
- Modify - treatment process - **mathematical models**
- Activated sludge models (ASM) - **BioWin© software**



- Study - process modifications using BioWin© - its implementation on existing operational STP (**KC valley - 55 MLD**) - meet new discharge standard
- Hypothesized - creation of **virtual anoxic zones** -bioreactor - coupled with modifications - operating parameters – **HRT, DO, MLSS and R ratio** - result in **SNDN and EBPR**
- Model was validated - validated model - used to identify optimum conditions - process modifications
- Several sensitivity studies -to assess combined effect of various operating conditions

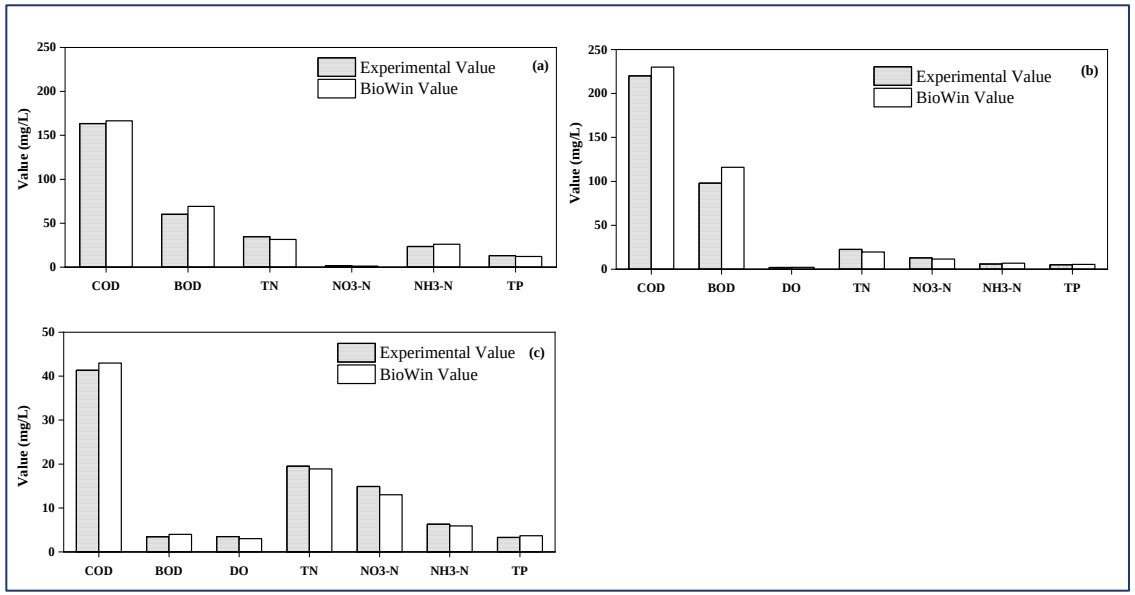
Parameters	Units	K&C Valley 55 MLD Unit Raw Sewage Characteristics	K&C Valley 55 MLD Unit Treated Water Characteristics	Treated Water Discharge Standards CPHEEO 2013
pH Value	-	8.5 ± 1.0	7.0 ± 1.0	6.5-9.0
Total Suspended solids	mg/L	230 ± 10	22 ± 5	< 10
Biochemical Oxygen Demand (5 day at 25°C)		193 ± 5	6.4 ± 1	< 10
Chemical Oxygen demand		448 ± 10	39 ± 5	< 50
Total Nitrogen		**39.2 ± 3**	**20 ± 2**	**< 10**
Ammonical Nitrogen		28.2 ± 2	5.1 ± 3	< 5
Dissolved P		**15.3 ± 2**	**3.5 ± 2**	**< 2**
Fecal Coliform	(MPN/100 ml)	10E-06 ± 1 E-06	190 ± 10	< 230

BioWin Model



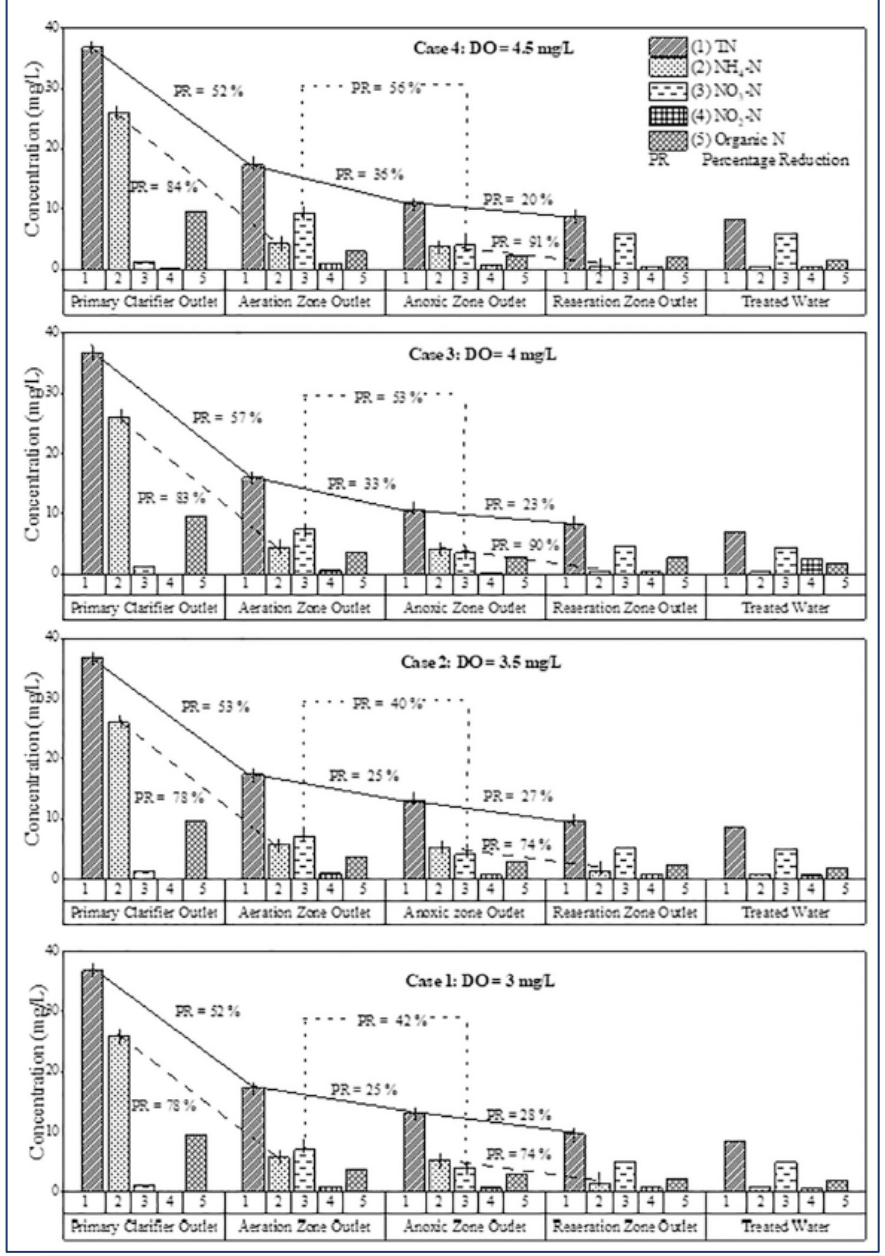
KC valley 55 MLD unit with blowers for air supply

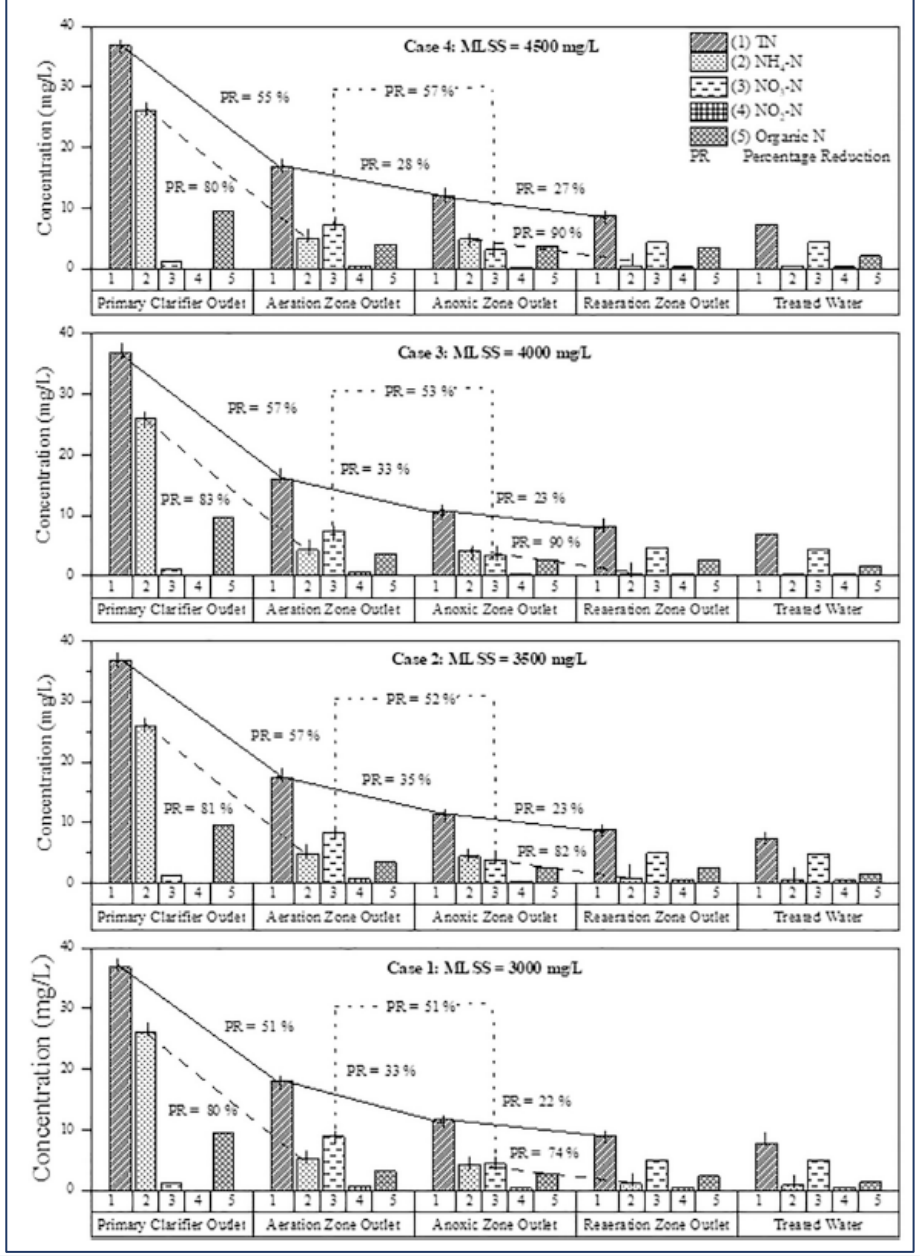
Model Validation & Sensitivity Analysis



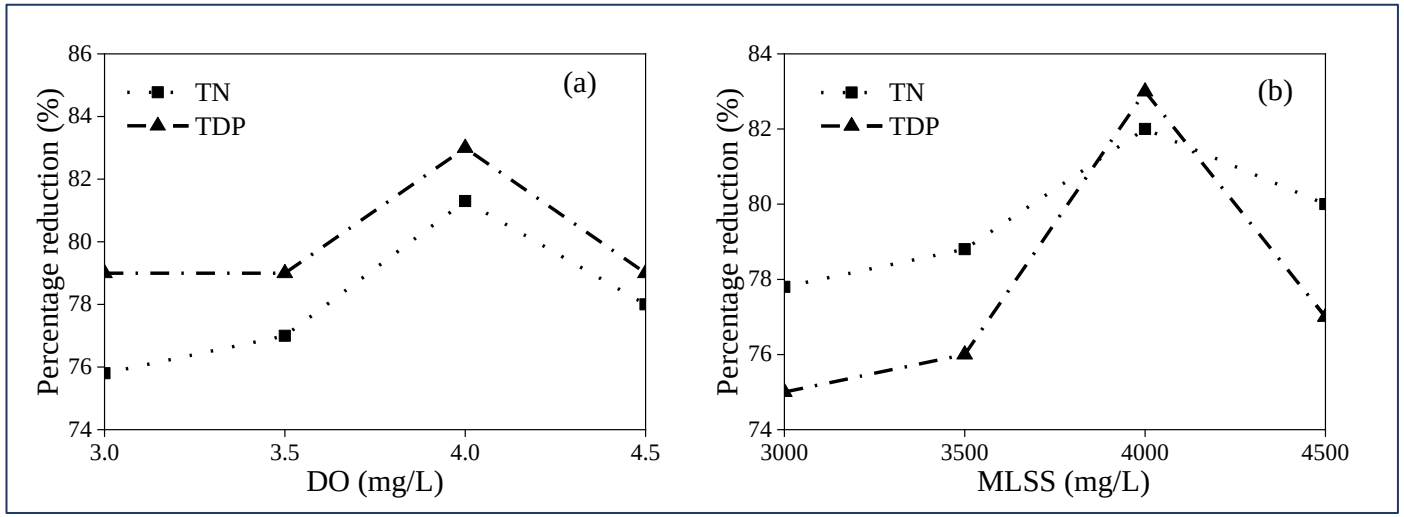
Comparison of experimental and BioWin© simulation values (baseline scenario) at (a) Primary clarifier outlet (b) Aeration tank outlet and (c) Treated water

- Relative error between - simulation value & experimental value - 4.9%, 5.6, 2.0, 6.0, 5.0, 6.1 and 2.5% for COD, BOD, DO, TN, NH4-N, NO3-N and TDP (as PO4)
- **Error was within acceptable limit of 10 %**
- **Developed BioWin© model - considered validated** for baseline scenario (before modification)



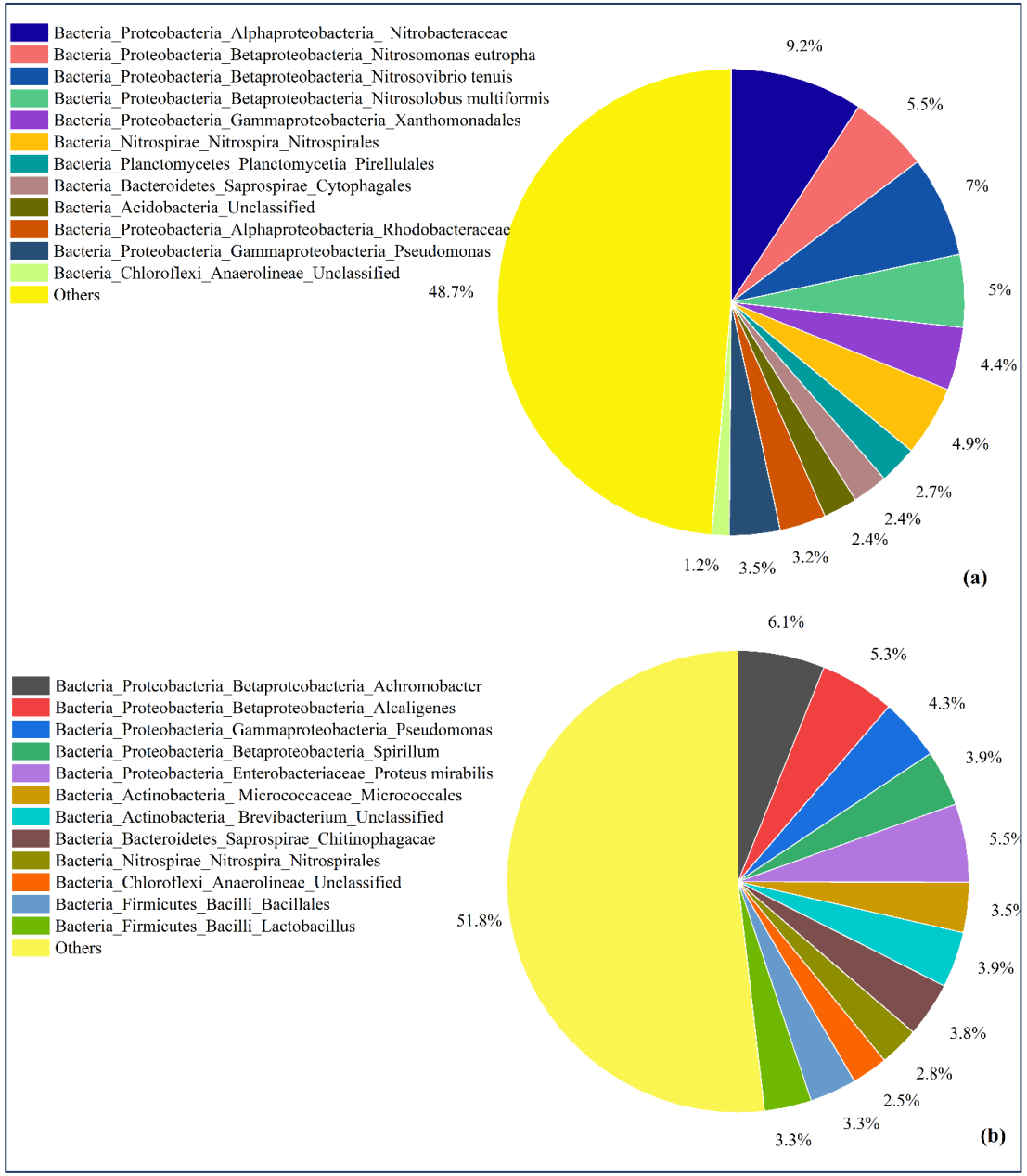


Simulation results of variation of (1) TN, (2) NH_4-N, (3) NO_3-N, (4) NO_2-N and (5) Organic N at each stage of treatment and at different Do and MLSS concentration; PR: Percentage reduction (calculated between each stage of treatment) of TN, NH_4-N and NO_3-N.



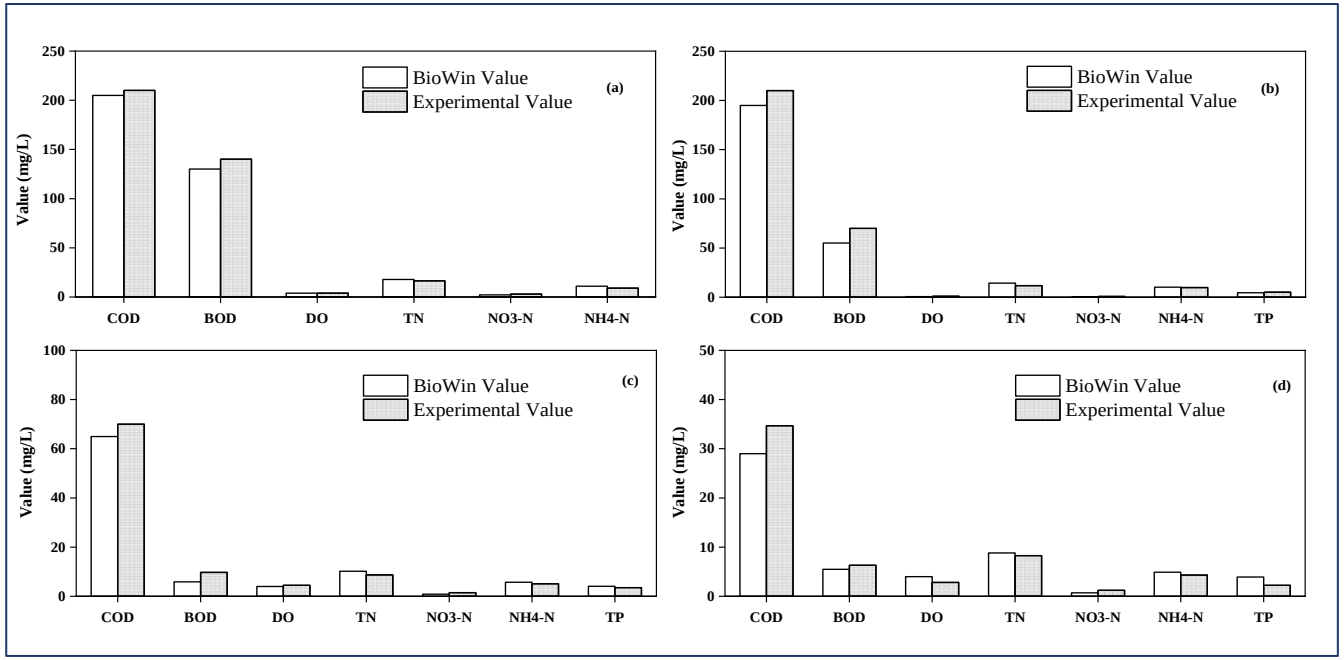
PR_o: Percentage reduction (raw sewage to treated water) of TN and TDP (as PO_4) with (a) DO concentration (b) MLSS concentration in aeration and reaeration zones

- TN and TDP concentration increased with DO of 4 mg/L – to improved SNDN by autotrophs and heterotrophs
- At higher DO of 4.5 mg/L- PR of TN decreased - attributed to inadequate HRT in anoxic zone to denitrify higher NO_3-N formed
- At higher DO levels - efficiency of TDP (as PO4) synthesis by PAOs - lower - high DO reduces uptake of PO4-P
- Potentially leave lower BOD for anaerobic processing
- Reason for higher TDP (as PO4) at DO of 4.5 mg/L.



Microbial class composition (in percentage) in (a) aerobic and (b) anoxic samples

- There was **clear difference in bacterial community** in aeration and anoxic samples
- **Aeration** samples - abundant in **ammonia and nitrite-oxidizing bacteria**
- **Anoxic** samples - rich in **denitrifying bacterial classes**
- Presence of **anaerobic PAOs** detected – **anoxic** samples
- **Confirms** hypothesis - **proposed modification** - successful in **EBPR**



Comparison of experimental and BioWin© simulation values (after modification of plant) of (a) Aeration zone outlet (b) Anoxic zone outlet (c) Reaeration zone outlet (d) Treated water

Water quality before and after treatment

- Relative error -simulation & experimental values - lower than acceptable upper limit of 10%
- Treated water **COD - 29 mg/L** -within limit of 50 mg/L.
- BOD5 - **5.5 mg/L** within upper limit of 10 mg/L
- TN - **8.8 mg/L** – within upper limit of 10 mg/L.
- Validated - introduction of nitrification – denitrification zones (aeration- anoxic-reaeration) - **optimized operating conditions - successful** - meet revised discharge standards.
- TP - **4.25 ±0.5 mg** P/L -within - discharge limit of 4.5 mg P/L

Estimated, actual cost and savings (in dollars) for the implementation of proposed modification

Sl. No.	Particulars	Estimated amount (In dollars)	Actual amount (In dollars)	Savings (In dollars)
1	Civil works including piping, erection, testing and commissioning	**$ 20310**	**0**	**$ 20310**
2	Supply of mechanical and electrical			$ 608300
	(a) Addition of submersible diffusers	$ 608300	0	$ 2038540
	(b) Addition of blowers for air supply	$ 2038540	0	
	(c) Addition of pipes and valves	$ 147490	0	$ 147490
	(d) Addition of 110 KW motor feeder for blowers	$ 33960	0	$ 33960
	Total	**$ 2828290**	**0**	**$ 2828290**
3	Chemical cost for a year			
	(a) Alum	$ 700000	0	$ 700000
	(b) Polyelectrolyte	$ 1902490	0	$ 1902490
	Total	**$ 2602490**	**0**	**$ 2602490**
4	Operating cost for a year	**$ 548910**	**$ 400000**	**$ 148910**
5	Total cost	**$ 6000000**	**$ 400000**	**$ 5600000**

- Modifications implemented in plant - minimum process intervention - resource investment & without shutting down plant
- Time for implementation & stabilization -8 months
- Cost for implementation - only **US$ 0.4 million - against initial estimate of US$ 6 million**
- Without shutting down plant operation, constructing new reactors
- Significant improvement - treated water quality - achieved in a short period of time

Conclusion

- Existing 55 MLD bioreactor divided virtually into aeration, anoxic and re-aeration zones – BioWin model
- Identified the **optimum conditions**
- TN & TDP - reduced - **20 mg/L to 8 mg/L and 3.5 mg/L to 0.9 mg/L**
- **Capital cost saving - US $ 5.6 million**
- **Adaptable onsite modifications successful with minimal plant shutdown**
- **Process modification- applied to other STPs – developing countries**

Reference:

Mohan T, R. et al. (2022) 'Achieving biological nutrient removal in an old sewage treatment plant through process modifications – A simulation and experimental study', Journal of Water Process Engineering. Elsevier Ltd, 45(July 2021), p. 102461. doi: 10.1016/j.jwpe.2021.102461.