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Using ANN to model the biological removal of nitrogen compounds from al-Musayyib's domestic wastewater using an SBR system

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Abstract:

The process of the biological removal of nitrogen compounds from wastewater that carried out in two stages and includes both nitrification and de-nitrification. Nitrification carried out under aerobic conditions using nitrosamines, which convert ammonia to nitrite. This unstable compound quickly converted to nitrate by nitrobacterium bacteria. This paper details the treatment of real domestic waste water from Al-Musayyib city, Babylon by conducting a laboratory scale batch reactor with different input samples and a variety of cycle times (6, 7, 7.5, 10 and 15 hours). The exploratory outcomes investigated for the detailing of a bolster forward, back-engendering, fake neural system (ANN) to foresee the proficiency of the consolidated expulsion of NO3, and NH3. ANN displaying did utilizing MATLAB's neural system tool compartment and SPSS programming. The removal efficiency of Nitrate (NO_3-N) increased when the anaerobic time (AN) of cycles increased, while the removal efficiency of Ammonia (NH_3-N) increased when the aerobic time (A) of cycles increased. Removal rates were between 88 and 97.5% for Nitrate (NO_3-N), 12.8 and 87.3 % for Ammonia (NH_3-N). As per the outcomes, this sort of treatment can utilized to expel nitrogen mixes from local wastewater and for different circumstances where the release is moderately low or temperamental.

Keywords: Domestic Wastewater, Sequence Batch Reactor, Artificial Neural Network NO_3-N & NH_3-N Removal.

Introduction

Each community produces both fluid and solid waste and related air discharges. Fluid waste (wastewater) the water from a group after utilized. This wastewater may characterized as a mix of the fluid or water-borne squanders expelled from living arrangements, foundations, and business and mechanical foundations, together with whatever groundwater, surface water and tempest water as might be available [1]. One way to the treatment of wastewater is by a Sequencing Batch Reactor (SBR). A SBR framework can made out of at least one tanks. In natural waste treatment, each tank in the framework has five essential working periods. These periods are FILL, REACT, SETTLE, DRAW and IDLE, these happening in a set time arrangement . Over each cycle, initiated slime settles after the response, the pro fluent drawn off and new in fluent included as definite underneath.[2]

Fill: Amid the fill stage, the bowl gets in fluent wastewater. The in fluent acquires nourishment to the organisms the initiated slop, making a situation for biochemical responses to occur. Blending and air circulation can balanced amid the fill stage to make three distinct situations: Static Fill, Mixed Fill and Aerated Fill.

React: Amid this stage, no wastewater enters the bowl and the mechanical blending and air circulation units are on. Since there are no extra volumetric and natural loads, the rate of natural expulsion increments drastically. The majority of the carbonaceous BOD evacuation and further nitrification happens in the respond stage.

Settle: Amid this stage, activated sludge permitted to settle under quiet conditions. No stream enters the bowl and no air circulation or blending happens.

Draw: Amid this stage, a decanter utilized to expel the reasonable supernatural gushing. Once the settle stage is finished, a flag sent to the decanter to open the gushing release valve, the reasonable supernatural released as pro fluent.

Idle: This progression happens between the empty and fill periods of the following cycle. Sit without moving time differs in view of the in fluent stream rate and the working methodology. Amid this stage, abundance slime (concentrated solids) delivered amid the cycle drawn out from the base of the SBR bowl for additionally preparing and transfer.

An Artificial Neural Network (ANN) is a numerical or computational model that is motivated by the structure as well as utilitarian parts of natural neural systems. A neural system comprises of an interconnected gathering of simulated neurons, which process data utilizing a connection way to deal with calculation.

ANN is a versatile framework that progressions its structure in view of the outer or inner data that courses through the system amid the learning stage. They typically used to show complex connections among information sources and yields or to discover designs in information. Neural systems can characterized as an interconnection of basic handling components whose usefulness in light of the organic neuron. An organic neuron is an interesting bit of gear that conveys data, exchanging this to different neurons in the system chain .[3].

Fig. (1) is a schematic drawing of typical neurons known as handling components (PEs), or hubs, the contribution from every PE in the past layer (X_i) increased by a customization association weight (W_{ij}) at every PE. The weighted information signals summed and an edge esteem (θ_j) might be included. This joined information (I_j) is then gone through an exchange (initiation) capacity to create the yield of the PE (Y_j) .[4],[5]

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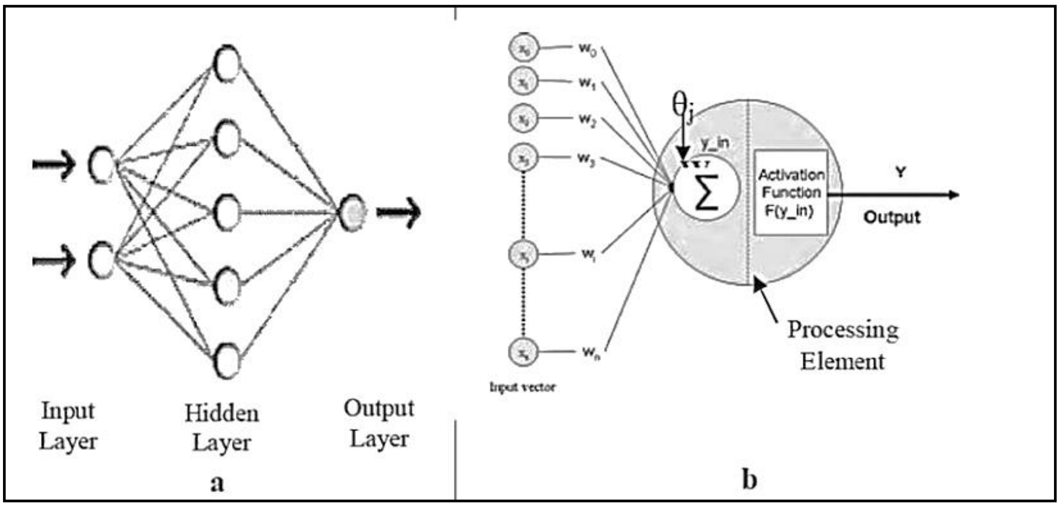

Fig. 1: Typical structure and typical neurons .[4]

The yield of one PE gives the contribution to the PEs in the following layer. This procedure abridged in conditions (1) and (2) .[4]

$$I_J = \sum W_{ij} X_i + \theta_j \quad (1)$$

$$Y_j = f(I_j) \quad (2)$$

where: I_j is the initiation level of hub j; W_ij the association weight between hubs I and j; X_i the contribution from hub I , I = 0,1,… … ,n; θ_j the inclination or edge for hub j; Y_i the yield of hub j, and f the actuation work.

Description of the laboratory unit

Experimental tests were conducted in a pilot plant consisting of a primary sedimentation tank (equalization process), SBR tank (fill, react, settle, draw and idle processes), and ventilation unit and mixing unit. The schematic graph of the exploratory mechanical assembly appeared in Fig. (2).The equalization tank was 30 x 30 x 60 cm in length, width and height, respectively, used to represent the source of the untreated wastewater. The dimensions of the SBR tank were 20 x 20 x 40 cm in length, width and height, respectively with an effective depth of 35cm. This tank contains two openings; one at the bottom used to remove excess sludge out of the tank, the other about 20cm from the bottom, used to pull samples for testing and also to discharge the supernatant content from the tank. The ventilation unit consists of an air compressor and air pressure control meter with a required pressure of 0.2 MPa. This ventilation unit ends with a tube, which extends to the bottom of the SBR basin and is equipped with small holes to supply the basin with small bubbles of oxygen. This was the source of oxygen for the microorganisms during the aerobic phase. The mixing unit consists of a source of alternating current and a regulator for voltage and electrical resistance. This unit ends with a mechanical impeller designed to operate at a minimum speed in order to keep the activated sludge suspended in all parts of the wastewater to complete the biological treatment.

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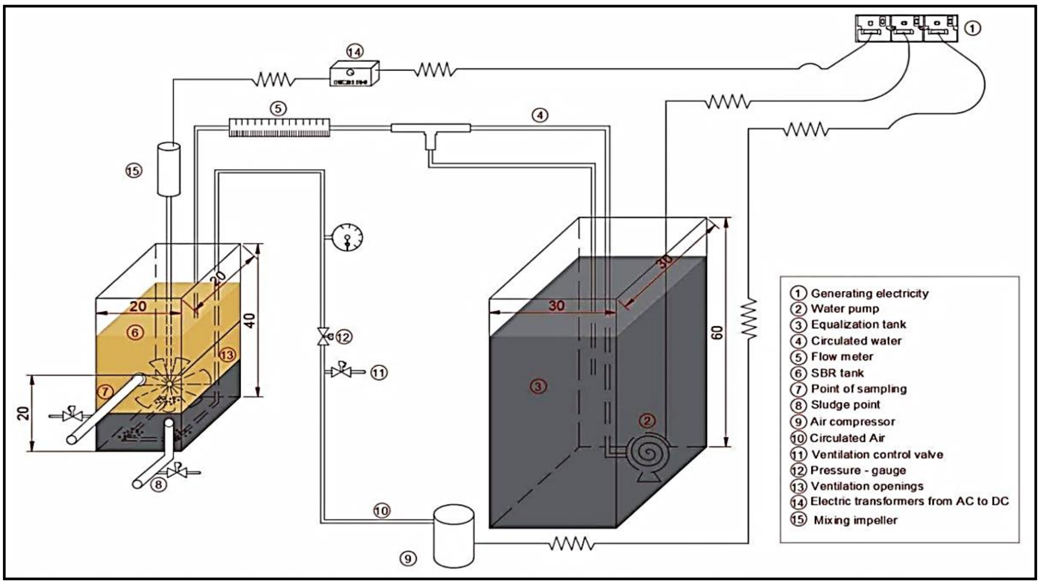

Fig. 2: Schematic diagram of the experimental apparatus.

The Operation Cycles

The system operated at a laboratory temperature of 16-25 °C over five cycles of 6, 7, 8, 10, 12 and 15 hours. Each of the five phases had a fixed percentage of the total cycle time: the fill phase was 25%, the react phase 35%, the settle phase 20%, the draw phase 15% and the idle phase 5%, as shown below in Fig.(3) [1].

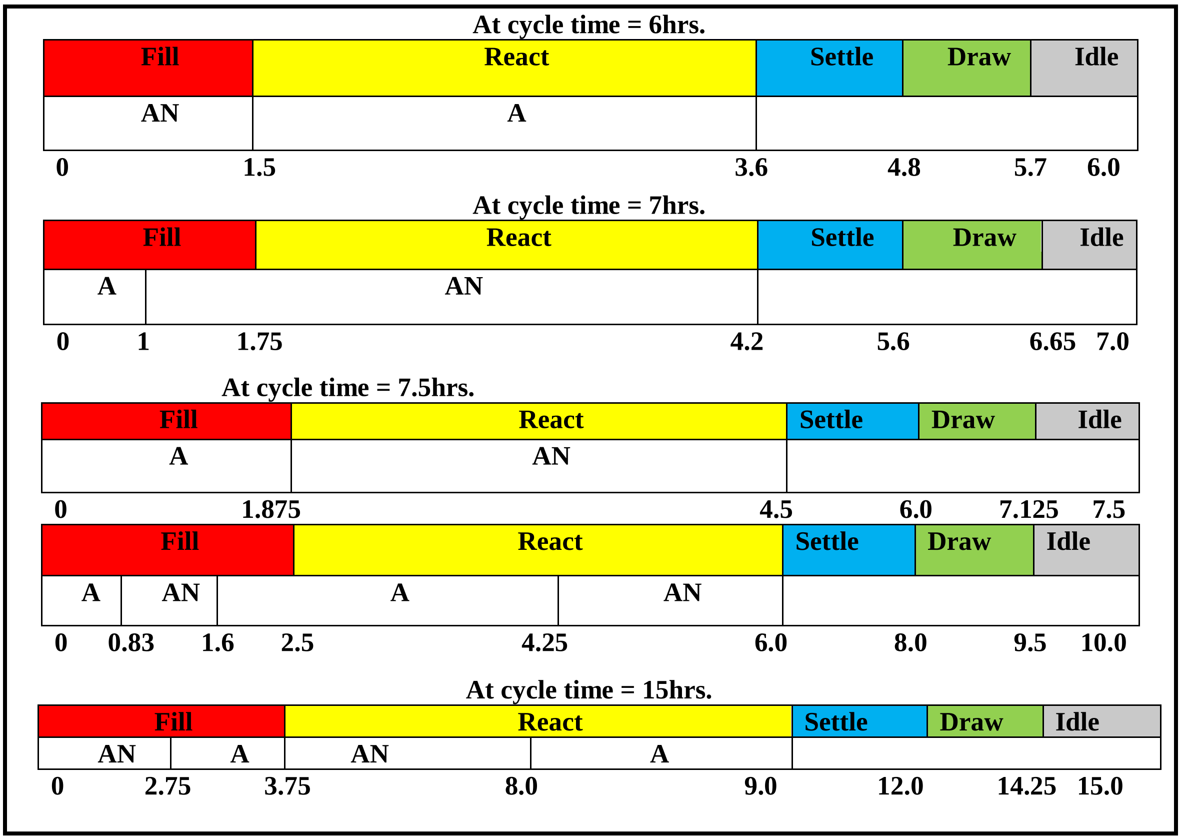

Fig. 3: Operated Cycles.

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Analytical Procedures

Experiments carried out using sludge seeds, supplied by the wastewater treatment plant in Al-Musayyib. The seed had developed to a concentration of approximately 3895 mg/L, which was within the range 2000-4000 mg/l.[1]; [6]. The development mechanism included the periodical addition of wastewater from the original wastewater treatment plant to the sludge seeds in the SBR basin, under a succession of aerobic-anaerobic conditions. This process was continued for one month. Following this, samples of raw wastewater brought daily for SBR treatment under different times and conditions. The characteristics of these samples are listed in Table 1. Raw and treated samples were stored at 4℃, preservatives such as chloroform added if necessary. All parameters were measured following the details and procedures as described in APHA, WPCF and AWWA tests and procedures .[7]

Table 1: The characteristics of the raw wastewater

Parameter	***Unit***	***Range***	***Average***
Potential of Hydrogen (PH)	-----	8.45-8.65	8.55
Electrical Conductivity(EC)	μs/cm	2212-2500	2356
Total Dissolved Solid (TDS)	mg/L	1073-2141	1607
Dissolved Oxygen (DO)	mg/L	2.62-3.50	3.06
Nitrate (NO_3)	mg/L	94-105	100
Ammonia (NH_3)	mg/L	7.5-9.1	8.3

Results and Discussion

The efficiency of the system at removing Nitrate (NO_3-N)

Figs. (3) and (4) detail the 6 and 15-hour cycles over which the concentration of nitrate decreased under anoxic conditions (AN) because of denitrification. Nitrate converted to nitrogen gas, as established by Sabri [8]. The effluent concentrations of the nitrate were 11.22 and 2.5 mg/l for 6 and 15-hour cycles, respectively. When the cycles were complete, the average influent value was 100 mg/l.

Figs. (5), (6) and (7) detail the 7, 7.5 and 10-hour cycles where it can see that the concentration of nitrate increased under aerobic conditions (A) because of the conversion of ammonia to nitrate by Nitrosamines and Nitrobacteria bacteria [11]. The effluent concentrations of NO_3 were 9.75, 12.57 and15.36 mg/l for 7, 7.5 and 10-hour cycles respectively. When these cycles were finished, the average influent value was 103 mg/l.

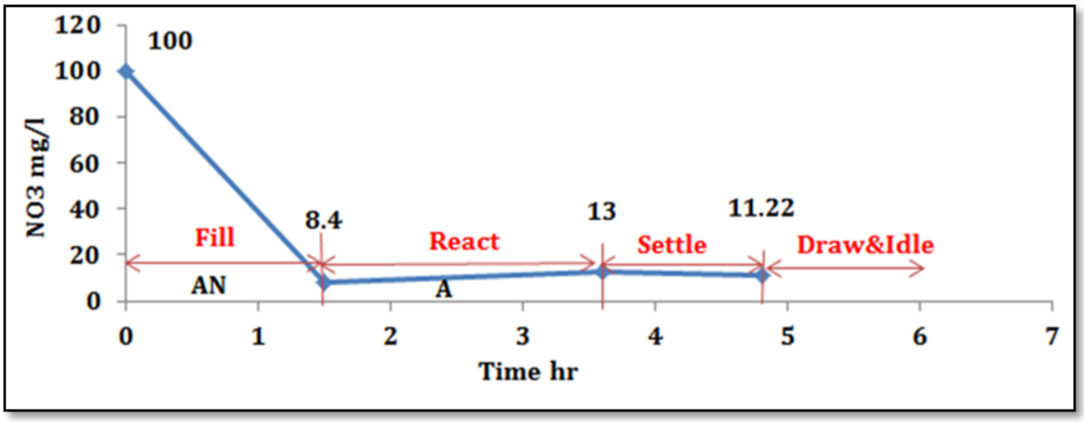

Fig. 3: Variations in concentrations of NO_3 during the 6 hour cycle

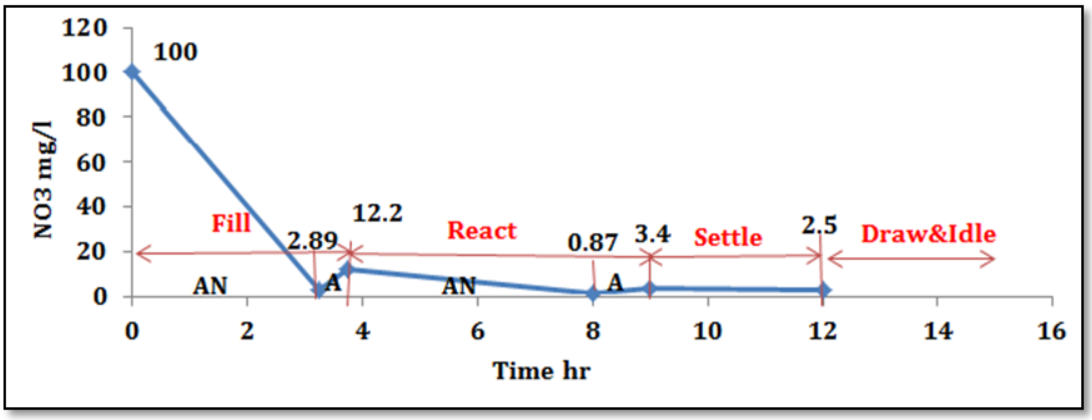

Fig. 4: Variations in concentrations of NO_3 during the 15 hour cycle

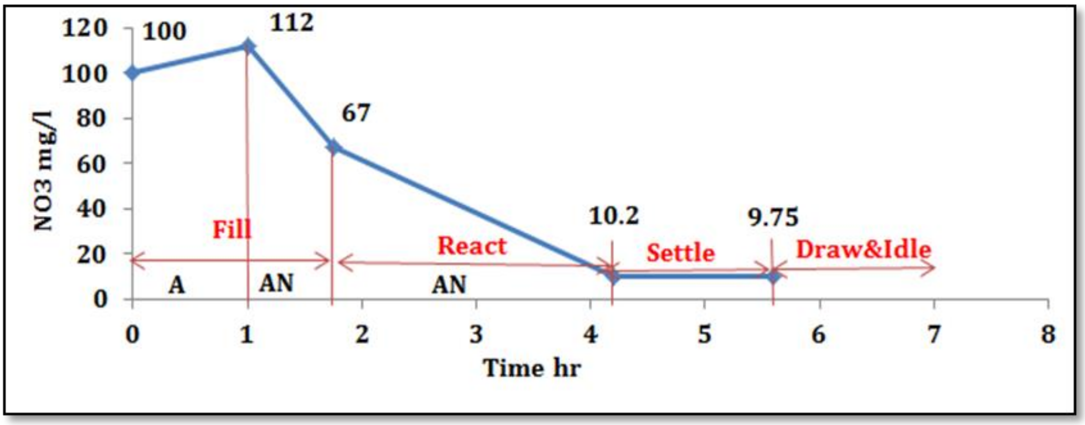

Fig. 5: Variations in concentrations of NO_3 during the 7-hour cycle

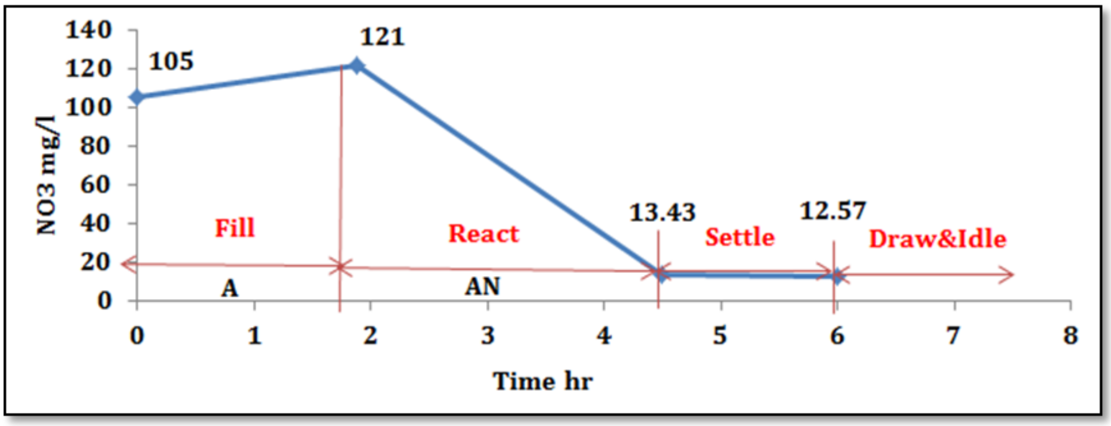

Fig. 6: Variations in concentrations of NO_3 during the 7.5 hour cycle.

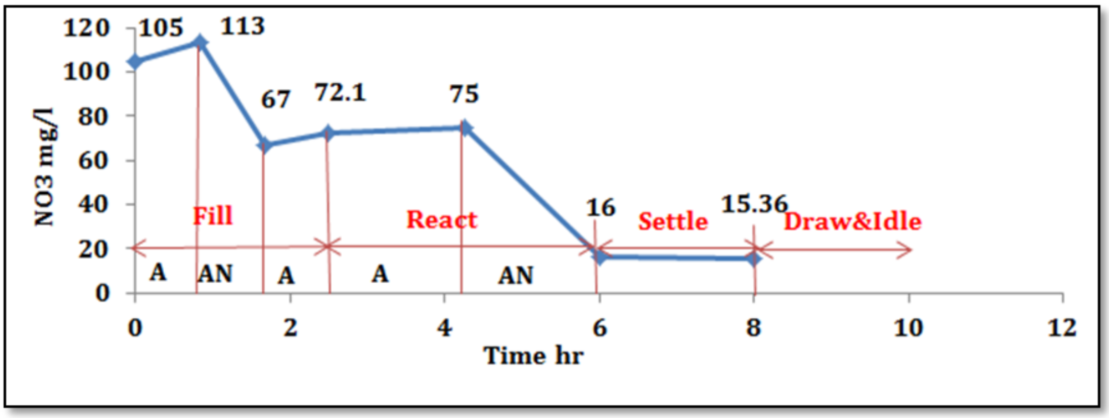

Fig. 7: Variations in concentrations of NO_3 during the 10 hour cycle.

Fig. (8) Shows the efficiency of the removal of nitrate computed over the 15-hour cycle. The increase in anoxic time (AN) during the phases of this cycle, led to an improvement in efficiency, this in agreement with Sabri [8].

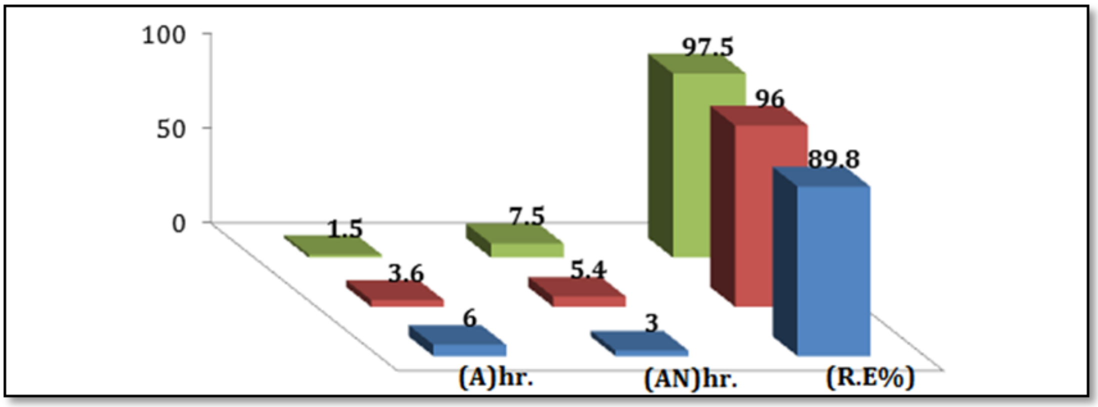

Fig. 8: Efficiency of the removal of NO_3 during the 15-hour cycle (Different Aeration Time).

Nitrate removal efficiency increases with an increase in the F/M ratio. This suggests that a proportion of food remained after completing the nitrification process. This remaining food was then used for nitrogen extraction. Microorganisms need the electron donor that comes from the food to convert nitrate to nitrogen gas under anoxic conditions .[9] as shown in Fig. 9.

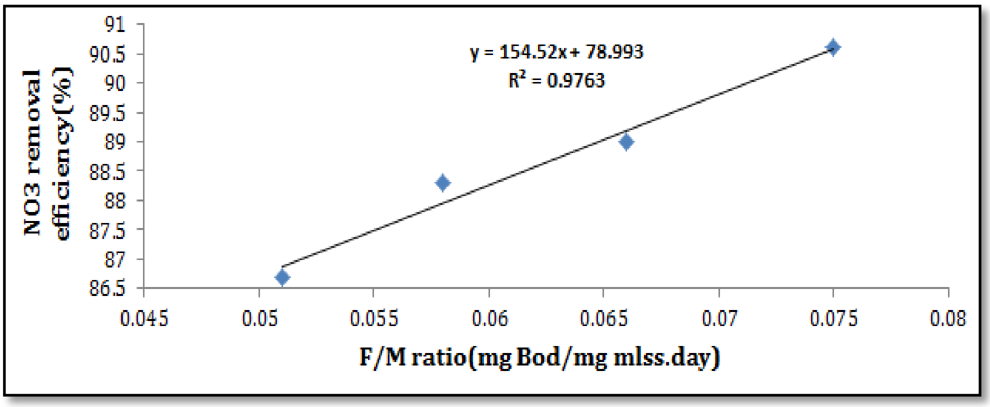

Fig. 9: Effect of F/M ratio on nitrate removal efficiency.

The removal efficiency of nitrate also increased with an increase in the COD/NO_3 ratio, this in agreement with Abufayad and Schroeder,[10] as shown in Fig. 10.

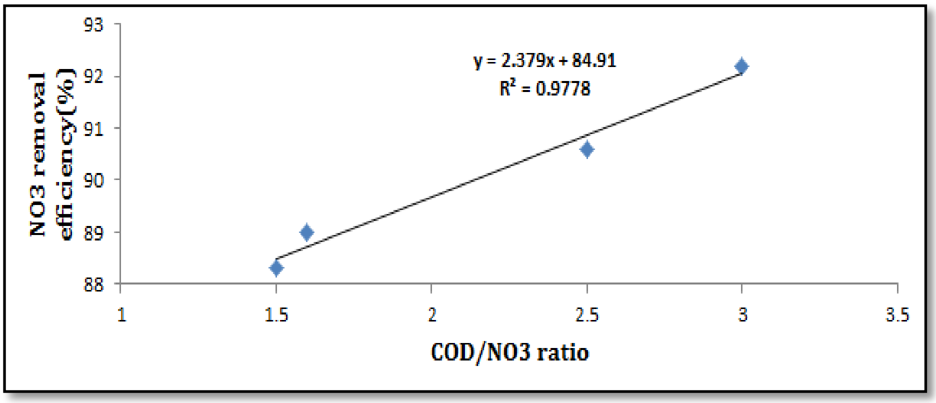

Fig. 10: Effect of COD/NO_3 ratio on nitrate removal efficiency

The efficiency of the system when removing Ammonia (NH_3-N)

Ammonia is removed by the nitrification process, the efficiency of this affected by the COD/NH_3 ratio [12], something which was also observed in the SBR system. When this ratio increases, the removal efficiency decreases, as shown in Fig. 11. An increase in this ratio signifies an increase in COD. If full oxidation does not occur, the ammonia cannot be removed.

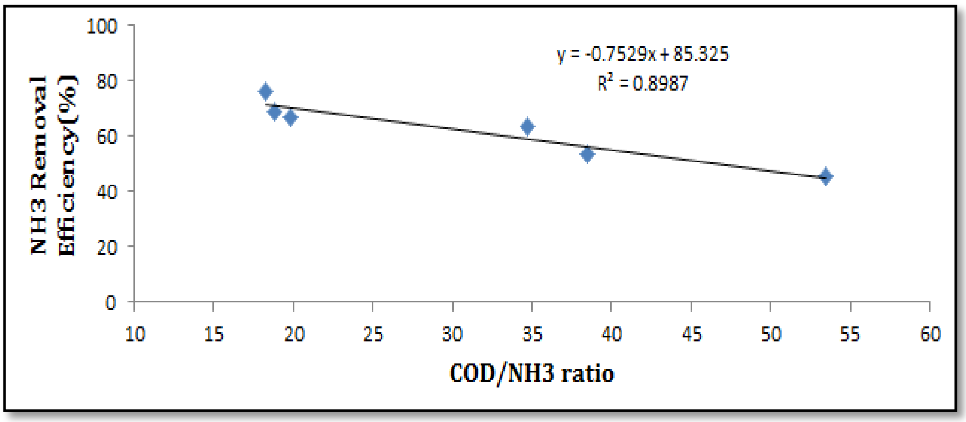

Fig. 11: Effect of the ratio of COD/NH_3 on ammonia removal efficiency

Ammonia removal efficiency also affected by the F/M ratio as shown in Fig. 12, where efficiency decreased with an increase in this ratio. Ammonia converted to nitrate as the organic load decreased in parallel with an increase in dissolved oxygen concentration [13]. According to the biological principles of the BOD test, the carbonaceous organic matter (CBOD) oxidized first followed by the nitrogenous organic matter (NBOD) .[14]

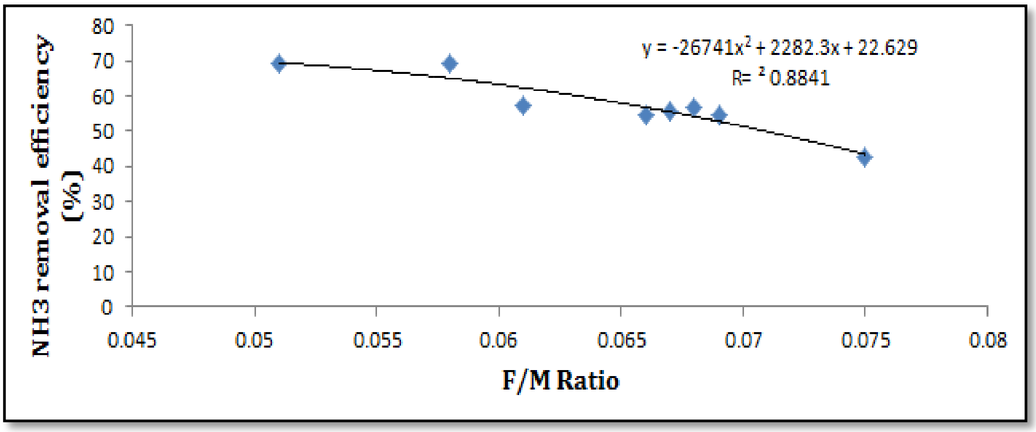

Fig. 12: Effect of the F/M ratio on ammonia removal efficiency.

In order to achieve an acceptable degree of nitrification, the contact time between wastewater and microorganisms should be longer than the time needed to remove the carbonic materials .[12] .As shown in Fig. 13, the removal efficiency of ammonia increased with an increase in cycle time.

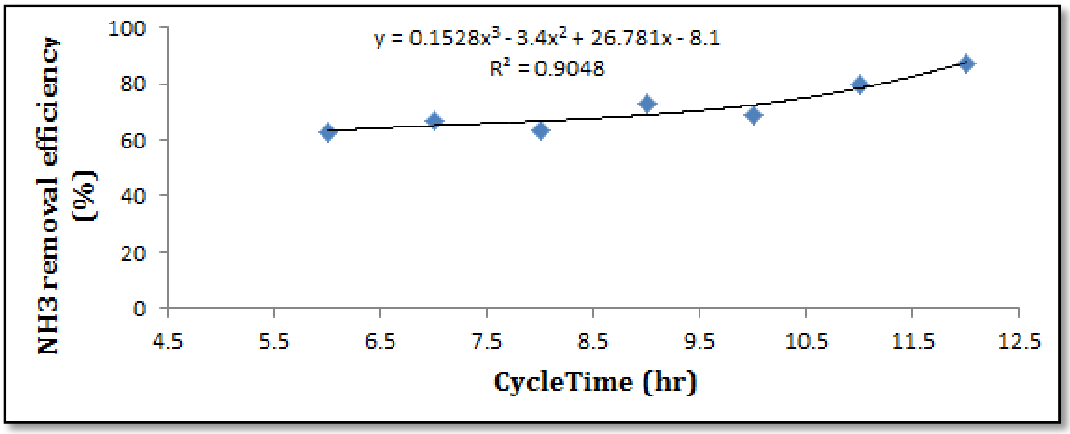

Fig. 13: Effect of cycle time on ammonia removal efficiency

Model of Percentage Removal

The first model to predict the percentage removed for each parameter used the influent properties as input variables. The model design for the input, hidden and output layers appeared in Fig 14. The training percent to anticipate this model was 75%, testing 15% and holdout 10% with 50 tests.

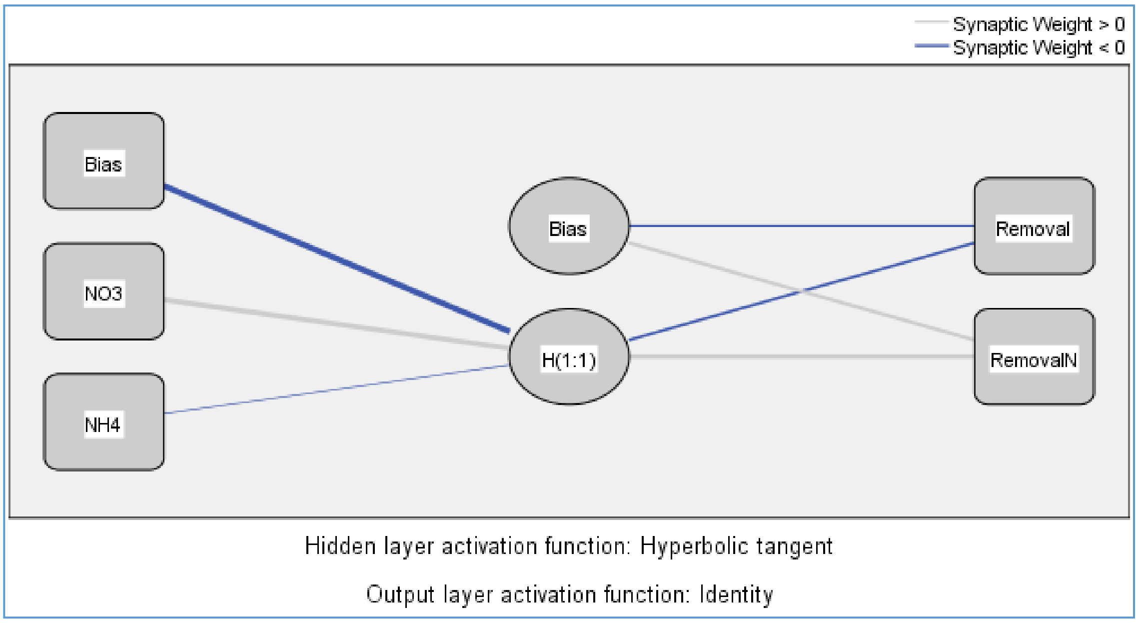

Fig. 14: The ANN model architecture for percentage removed for each parameter

Model of Total Cycle Time

The second model was to predict the total cycle time using the percentage removed after treatment as input variables. The model design for the input, hidden and output layers appeared in Fig. 15.The training percent to predict this model was 76%, testing 22% and holdout 2% with 50 samples.

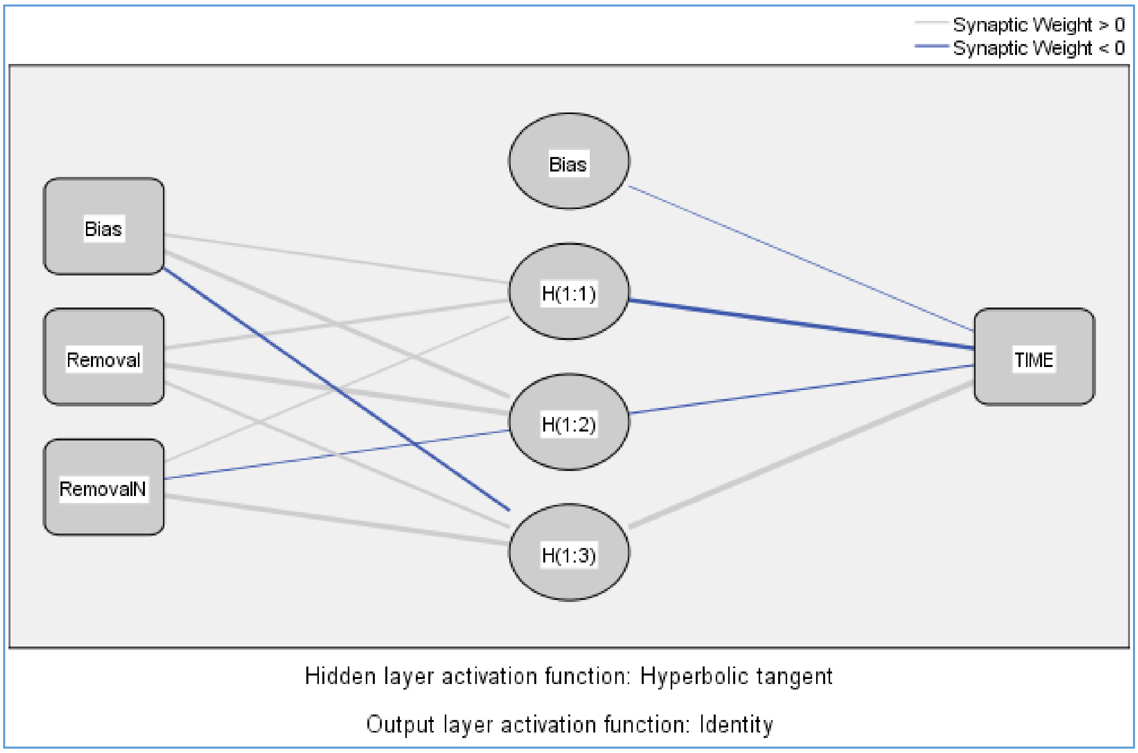

Fig. 15: The ANN model architecture for total time cycle

Model Verification

In order to check the validity of the models, all the cases tested estimated. Figures 16 and 17 show the comparison between these values and the measured tested values. It is clear that the model gives good estimates for the entire discharge coefficient in all flow cases, this considered a strong correlation if r ≥ 0.8, then a strong correlation exists between two set of variables. In Figs. 16 and 17, it is clear that the ANN model gives good estimations for the output variables, this also considered a strong correlation.

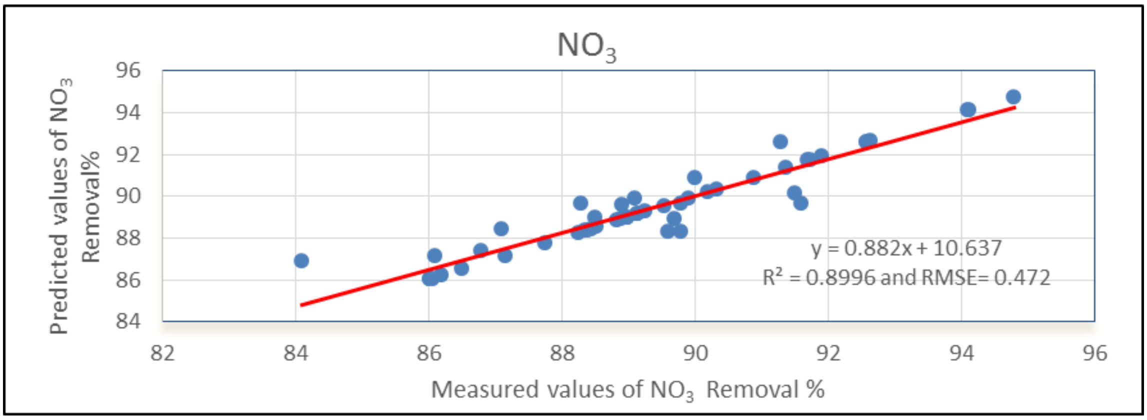

Fig. 16: Comparison between NO_3 estimated and measured values

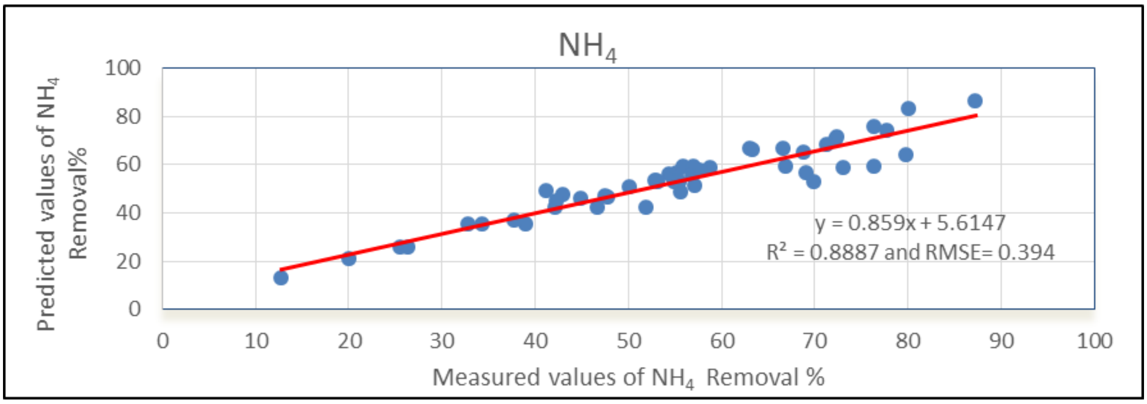

Fig. 17: Comparison between NH_4 estimated and measured values

Conclusions:

1. The removal efficiency of Nitrate (NO_3-N) increased when the anaerobic time (AN) of cycles increased
2. The removal efficiency of Ammonia (NH_3-N) increased when the aerobic time (A) of cycles increased.
3. Removal rates were between 88 and 97.5% for Nitrate (NO_3-N), 12.8 and 87.3 % for Ammonia (NH_3-N).
4. This type of treatment can utilized to expel nitrogen mixes from local wastewater and for different circumstances where the release is moderately low or temperamental.
5. ANN technique can be considered a good tool to predicted removal efficiency of Nitrate and Ammonia.

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