SIMULTANEOUS TREATMENT OF NITROGEN AND PHOSPHORUS FROM SECONDARY EFFLUENT: IF THE EAST WWTP OF TIZI-OUZOU (ALGERIA)

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Abstract

To ensure the objectives of quality of receiving waters, our study focuses on the one hand, on the physicochemical characterization of secondary effluent from the wastewater treatment plant (WWTP) east of the city of Tizi-Ouzou and secondly, on the development of an experimental pilot accommodated tertiary treatment simultaneous reduction of nitrogen and phosphorous pollution of treated wastewater. The driver in question actually allows a significant elimination of nitrogen and phosphorus, with returns of 89.10% and 94.46%, in addition to a significant improvement in the quality of pollution physicochemical parameters an efficiency of 91.64% for MES, 86.63% for COD and 88.36% for BOD_5.

Keywords: *wastewater treated, simultaneous removal, nitrogen, phosphorus, intensive process*

INTRODUCTION

Know the sensitivity and fragility of the receiving environments in Algeria, especially in times of low water which is spread over an average period of 8 months / year, and knowing that the treatment plants located throughout the country are without treatment that would permit the tertiary abatement of phosphate and nitrogen pollution. It is for this reason, as part of this work, we have considered applying for an experimental pilot tertiary treatment simultaneous reduction of these nutrients in a laboratory scale. Excessive presence of these two elements in different aquatic environments is undesirable and detrimental to the environment. Their reduction to swallow purifications systems is a key factor in the fight against pollution and eutrophication (Vasel, 1996). The guide values are regulated in Algeria by the 'Urban wastewater "(Official Gazette of the Algerian Republic, 2006). The main objective of this study is the optimization of coélimination tertiary treatment of nitrogen and phosphorus from secondary effluent treatment plant Is of the city of Tizi-Ouzou; by the development of an experimental pilot accommodated, operating by biological and physicochemical processes mixed.

Problematic nitrogen and phosphorus

Paradoxically, nitrogen and phosphorus are firstly in the eyes of farmers of essential nutrients in the soil-plant interface for the improvement and intensification of crop yields on the other side in the eyes of environmentalists water compartments excess presence is detrimental to the environment and public health. However, in recent decades, the growing trend of nitrogen and phosphate pollution, has led public authorities to strengthen the regulatory requirements of these elements, by appropriate treatment leading to uphold the quality objectives of natural environments receivers (Marsalek et al, 2001; Vasel, 2007).

The effluent discharge standards

The collected wastewater in urban or wastewater networks directly emitted by industries, should be released into a natural receiving water (river, lake, sea coast, or spreading ground) than when they correspond to standards fixed by regulation.

The Executive Decree No. 93-160 of 10 July 1993, the Official Journal of the Algerian Republic regulating discharges of liquid effluents in its Chapter I, Article 2, shall, in its Annex 1, the limit values of the rejection. These same values have just been strengthened by a new regulatory text; Executive Decree No. 06-141 of April 19, 2006, Section 1, Article 3. The maximum discharge limits set by the effluent two decrees are summarized in Table 1.

Table 1: discharge of treated effluent standards (Official Gazette of the Algerian Republic, 2006).

Parameters	**Limit values**	**Units**
Temperature	30	°C
Ph	6,5 à 8,5	-
MES	90	mg/l
COD	120	mg/l
BOD_5	35	mg/l
Total nitrogen	10	mg/l
Total phosphorus	2	mg/l

Before they are released into the environment and degrade the waste water must be transported to a treatment plant where they undergo several phases of treatment based on the flow of their pollution load and the sensitivity of the receiving water , discharge guideline values are shown in Table2.

Table 2: discharge of treated effluent standards (standards guides) (Faby and Brissaud, 1997).

pH :

5.5 <pH <8.5.
Temperature: less than 30 ° C.
COD:
- 150 mg / l For non decanted effluent,
- 300 mg / l if the maximum permitted daily flow does not exceed 100 kg / d,
- 125 mg / l beyond.

BOD_5:
- For non decanted effluent: 100 mg/l if the maximum permitted daily flow does not exceed 30kg/d,
- 30 mg / l beyond.

MES:
- 100 mg / l if the (flow) daily maximum allowed by the decree does not exceed 15 kg / d,
- 35mg / l beyond,
- 150 mg / l for a sewage lagoons..

NT:
nitrogen Total, including organic nitrogen, ammonia nitrogen and nitrogen oxidized: 15 mg / l monthly average concentration when the maximum permitted daily flow is equal to or greater than 150 kg / d,
-It Is 10 mg / l monthly average concentration when the maximum permitted daily flow is equal to or greater than 300 kg / day.

PT:
-Phosphorus Total: 2 mg / l monthly average concentration when the maximum daily flow allowed is equal or greater than 40 kg / d,
-It Is 1 mg / l monthly average concentration when the maximum daily flow authorized is over 80 kg / day.

Simultaneous Removal of phosphate and nitrogen pollution

Simultaneous Removal of phosphate and nitrogen pollution the elimination of phosphate and nitrogen pollution of domestic wastewater by primary and secondary treatment in STEP is insufficient. For this tertiary or complementary treatments are necessary and become more than necessary to ensure a better reduction of the pollution load in natural environments receivers (Rice, 1974; Lefevre, 1988; Vanderboght 1992; Vasel, 1996; Liu et al, 1997).

Some of the reduction techniques of these two nutrients, soil-plant systems, lagoons, activated sludge, biological and physicochemical mixed systems have been extensively studied by (Mara and Cairncross, 1989); (Junger 2000); (Lazarova et al, 2003) and (Vasel, 2007). They are used for removal of the order of more than 70% of nitrogen and phosphorus brought by the secondary waste water.

To contribute to this requirement and guarantee a total nitrogen concentration (Nt) and total phosphorus (Pt), respectively, less than 10 mg / l and 2 mg / l, we have developed and tested an experimental pilot biological and physico-chemical reactors, with an accurate optimization of aeration phases that would promote both the uptake and release of phosphorus as well as oxidation and reduction of nitrogen.

During the first two weeks, the unit has operated in closed circuit to allow colonization and planting different biological reactors by appropriate purifying microorganisms while maintaining the sludge recirculation to ensure them a sufficient age, thus improving the purification yields.

The parameters studied are:

- the SS, COD, BOD 5, Nt, Pt;
- the variation effluent flow from 0.5 to 2.5 l / h;
- the quantities of additives used for precipitation post phosphorus vary from 20 to 120 mg / l.

Features effluent treated in the STEP Is of the city of Tizi-Ouzou

The physicochemical characteristics of Table 3 pollution parameters represent a balance of one (01) year periods during extreme water (high water and low water).

Table 3: Means and standard deviations of the physico-chemical characteristics of the treated effluent.

Parameters	**Average**	**Standard deviation**	**Number of measurement**
MES (mg / l)	123,84	10,66	48
pH	7,8	0,75	48
Temperature (°C)	26,45	3,68	48
DCO (mg / l)	134,26	11,82	48
DBO_5 (mg / l)	82,68	4,35	48
Total nitrogen (mg / l)	58,95	6,25	48
Total phosphorus (mg / l)	13,55	2,43	48

The treated effluent has an N / P ratio of about 4/1 normal for traditional STEPS effluents that do not have tertiary treatment of nitrogen removal and phosphorus and which is also of interest for agricultural use. Indeed, levels of nutrients (nitrogen and phosphorus) wastewater after secondary treatment vary from 20 to 60 mg / l nitrogen and 6 to 15 mg / l phosphorus. Moreover, nitrogen as phosphorus, contained in treated wastewater interested in several titles the farmers in soil compartment, but undesirable for environmentalists and hydraulics in aquatic

environments because of their nuisance and / or toxicity. The regulation distinguishes between stations which discharge into non-sensitive area and one that rejects in sensitive areas; non sensitive area, only standards for carbon materials must be observed.

For the specific case of our study, the effluent is discharged directly for charging a sensitive groundwater table especially in times of low water, with a capacity of 100 million m3, which represents the main source of water supply drinking the wilaya of Tizi-Ouzou Algeria with a population of 1.2 million inhabitants, hence the need for treatment and abatements of these nutrients and MES, BOD_5 and COD.

Experimental pilot Description

This setup is placed in a room with temperature-controlled. Tests were performed for two years with the driver shown in (Fig. 1).

The apparatus is composed of reactors in series including:

- **An aeration basin**, the basin has a capacity of 10 liters, working in strict aerobic, aeration provided by a continuous injection of compressed air, allowing for fine bubble aeration type. The air flow is adjusted so that the dissolved oxygen concentration is greater than 3 mg/l. Fed by waters of the output STEP East of the city of Tizi-Ouzou. It simultaneously ensures the mineralization of organic nitrogen (nitritation and nitration) and phosphorus assimilation as energetic reserves (ADP, ATP) by the continuous recycling of a portion of the decanter sludge of engager the anoxic phase.
- **A cylindrical conical bottom decanter (buffer reactor):** It has a volume of 10 liters, it is the innovative part of the pilot ensuring both:
    - the role of a buffer tank engaging the anoxic phase subsequent denitrification reactor (trickling filter) fixed to crops to increase the stress phase for microorganisms that would promote a considerable release of phosphorus. This strict anoxic phase is also essential to increase yields of denitrification.
    - a third clarification;
    - recycling of sludge to the aeration tank in order to have a sufficiently large biomass of age to ensure better oxidation of ammonia nitrogen and phosphorus uptake bloated by the effect of alternating aeration phases extreme;
    - separation of nitrifying and denitrifying purifying biomass.
- **A submerged bacterial bed:** this is a cylindrical column capacity equal to 10 liters of water to treat, filled with traditional upholstery composed of ferruginous sandstone with a diameter of 5 to 10 mm with a high specific surface. It is fed by gravity through the settling tank, it ensures both denitrification and leaching of phosphorus assimilated during the aeration phase.
- **A post precipitation basin:** ensuring post-precipitation of the phosphorus released during the anaerobic phase as ortho-phosphates.
- **peristaltic pumps and an air compressor:** respectively for circulating the effluent and oxygenation

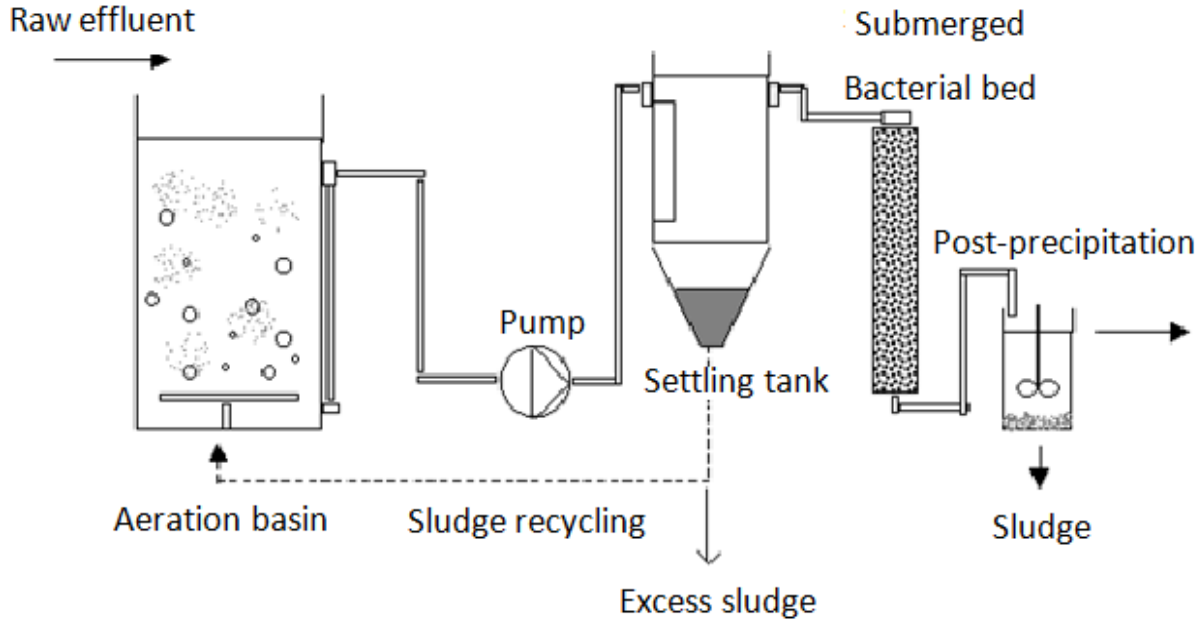


Figure 1: Schematic of the experimental setup.

The driver is continuously fed with the treated effluent from the STEP Is of the city of Tizi-Ouzou. The sampling twice daily (morning and evening) Water is at the exit of the secondary clarifier. We studied the purification yields by applying (04) four rates of 0.5 l/h, 1 l/h 1.5 l/h and 2 l/h respectively corresponding to (04) stays of time.

For the rest of this section we present only the results performed with the flow 02 l/h, corresponding to a time stays (05) five, being sufficient to ensure quality objectives required standards and receiving environments.

Application driver for abatement (MES, COD, BOD $_5$)

We present in this part of the results yields abatement above mentioned parameters after they pass through our pilot plant, under the following operating conditions:

- Operating flow rate: 2 l / h;
- MES 123,84 mg / l;
- COD 134.26 mg / L;
- BOD 82.68 mg / l;
- total nitrogen load 58,95 mg / l;
- total phosphorus loads 13,55 mg / l;
- Oxygenation capacity under pressure of 1 bar;
- Ambient temperature laboratory between 24 and 28 ° C.

Variation MES

The (fig. 2) shows that the passage of effluent in the pilot unit improves the solids concentrations of the effluent already addressed 123.84 mg / L to 10.35 mg / L, a satisfactory value compared to the

rejection of Algerian norm of 35mg / l. The combined abatement rate of buffer tank and post-precipitation reached a yield of 91.64%.

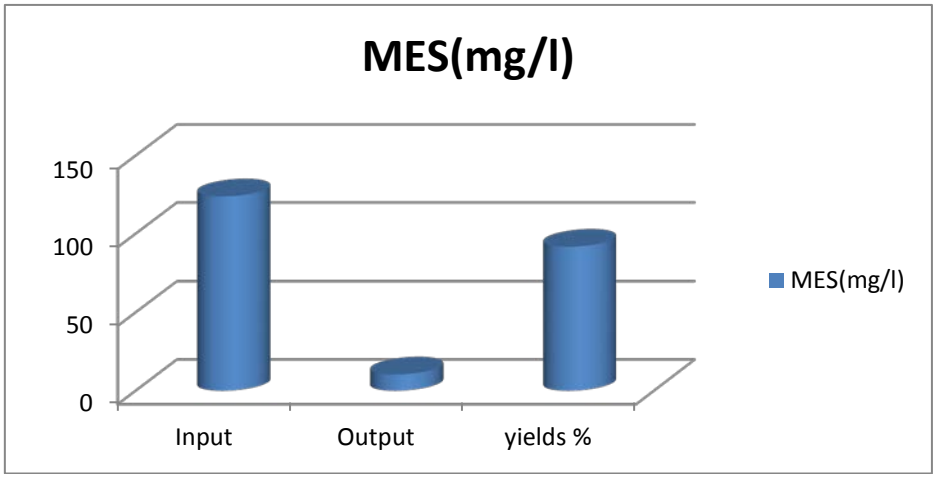


Figure 2: Influence of the pilot unit on the abatement of MES.

Variation of the chemical oxygen demand (COD)

In (Fig. 3) shows the evolution of the DCO, where we observe significant abatement during the passage of the effluent in the pilot unit. The concentration is reduced 134,26mg / l at 17,94mg / l representing a yield of 86.63%.

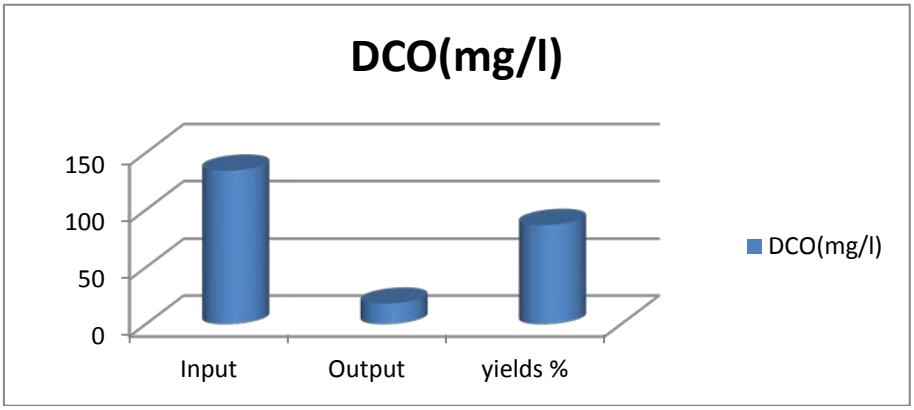


Figure 3: Influence of the pilot unit on the reduction of COD.

Variation of biochemical oxygen demand BOD_5

The analyzes performed on the output of the water treatment plant after primary and secondary treatment, show that the values of BOD5 are high (82.68 mg / L) compared to the Algerian guide value is 35 mg / l.

A significant reduction in 82,68mg / l to 9,62mg / l of BOD5 is observed with a yield of 88.36% as shown in (Fig. 4).

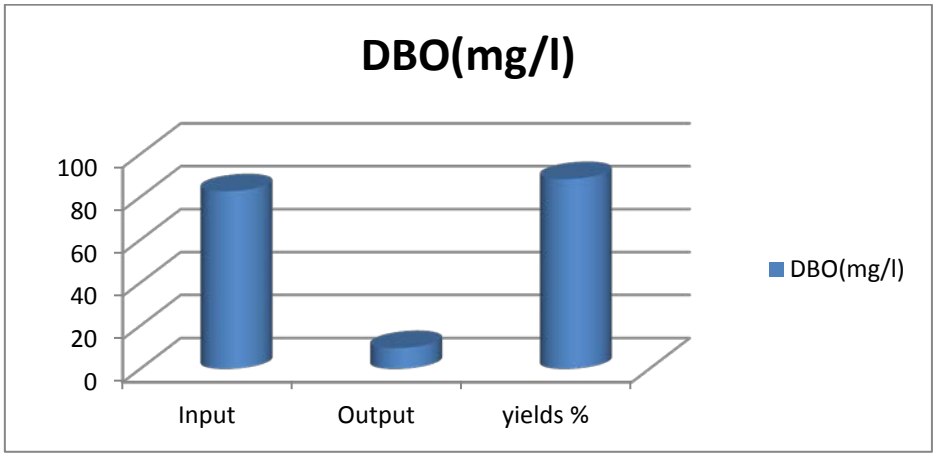


Figure 4: Influence of the pilot unit on the reduction of BOD_5.

The experimental device has significant aptitudes in abatement pollution parameters (MES, COD and BOD_5) of treated wastewater at very acceptable quality levels Table 4 and thanks to the coupling of physicochemical and biological treatments.

Application driver for the simultaneous removal of nitrogen and phosphate pollution

This part of the experiment and performed in operating conditions given below:

- operation flow 2 l / h, corresponding to a residence time of 5 hours;
- nitrogen load raw effluent 58.95 mg / l of $N\text{-}NH_4$ / l;
- phosphate load of the raw effluent 13,55 mg / l;
- oxygenation capacity, under a pressure of 1 bar.

En aerobic phase

The overall reaction, linked to cell syntheses, reports the action of two groups of microorganisms on ammonium (the nitrifiers). These germs, one of which is nitritant (Nitrosomonas) and the other nitrating (Nitrobacter) are strict aerobic and draw their energy from the oxidation of ammonium.

$$NH_4^+ + 1{,}83O_2 + 1{,}98HCO_3^- \longrightarrow 0{,}021\ C_5H_7NO_2 + 1{,}04\ H_2O + 0{,}98\ NO_3^- + 1{,}88\ H_2CO_3$$

this reaction is possible in sewage plant if BOD5 is sufficiently mineralized and if conditions are adequate oxygenation:

- the amount of BOD5 (carbon and energy source heterotrophic) should be low enough so that the nitrifiers are not in competition with heterotrophic germs to ammonium (nitrogen source and energy). The generation time heterotrophic being 30 minutes to 1 hour, against 24 hours for nitrifiers, these may represent the dominant species and sequester ammonia and oxygen at the expense of nitrifiers;
- dissolved oxygen (free) greater than or equal to 3 mg / l.

In Table 5 is demonstrated the oxidation phase of the ammoniacal nitrogen and phosphorus assimilation in the aeration basin, following alternating extreme ventilation phases (aerobic and anoxic).

Table 5: oxidation of nitrogen and phosphorus assimilation by strictly aerobic

parameters	**secondary effluent to process**	**output of the aeration basin**
$N\text{-}NO_3^-$ (mg/l)	1,13	43,12
$P\text{-}PO_4^{3-}$ (mg/l)	11,66	3,34

The results reported in Table 5, illustrated in (Fig. 5) show firstly an important nitrification in the aerobic phase in which the concentration of nitrate increased from 1,13mg / l to 43,12mg / l. On the other hand, a net uptake of phosphorus whose concentration password 11,66mg / l to 3,34mg / l and after the recirculation of the sludge in the two extreme cooling phases (aerobic and anoxic). This recirculation of the anoxic reactor sludge to the activation tank microorganisms subjected successively under optimal conditions and stress. These requirements and repeated microorganisms respectively induce absorption, then a release of phosphorus. The object sought in this succession of phases optimal and stress is to observe the phenomenon of plethoric assimilation of phosphorus by the microorganisms in order to have a good yield of phosphorus abatement by microorganisms, thereby ensuring a significant release in anoxia subsequent phase of the bacterial bed.

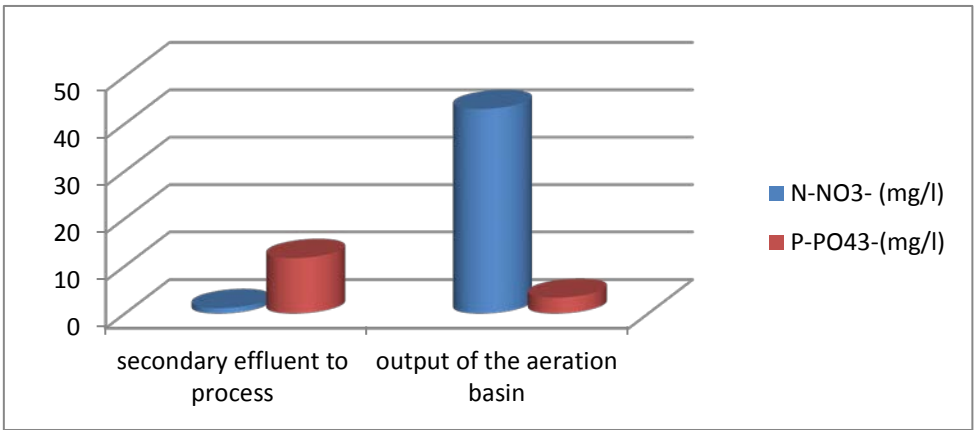


Figure 5: mineralization of nitrogen and assimilation of phosphorus in the aeration basin.

In Phase anoxia

This reaction, linked to cell synthesis is catalyzed by strictly aerobic bacteria chemoorganotrophs practicing the anoxic respiration. Nitrates, from the nitrification, serve as final electron acceptor and proton in the breathing process

$$97NO_3^- + 50CH_2OH\text{-}CH_3 + 97\,H^+ \longrightarrow 5C_5H_7NO_2 + 75CO_2 + 181H_2O + 46N_2$$

(organic matter) (biomass)

Unlike the aerobic process, the reaction in anoxic phase is possible only under the following conditions:

- When the BOD5 content is sufficient to allow the development of denitrifying heterotrophic;
- When anoxic conditions are put in place, that is to say in the presence of oxygen bound (NO_3^-) and absence of free oxygen in order to foster breathing on nitrates.

The innovative part of this pilot reactors in series, is the presence of the buffer decanter which optimizes the different phases of ventilation, ensuring in particular the following operations:

- absorption of free oxygen resulting of the aeration basin and engagement of strict anoxic conditions for the bacterial bed;
- Promotes the natural sequence of nitrification and denitrification processes;
- plethoric Leaching of phosphorus in the bacteria bed;
- recirculation sludge from the stress of phase to the optimal phase to encourage assimilation and release of phosphorus, respectively, in the activation tank and in the bacterial bed;
- Separation of purifying biomass free culture in the aeration phase and that of the fixed cultivation anoxic phase, to optimize nitrogen ammoniacal mineralization process by the reactions of nitrification and denitrification;
- Second clarification;
- Removal of excess sludge with nitrogen and phosphorus

This joint elimination of nitrogen in various forms (NH_4^+, NO_3^-) is very difficult to implement in a conventional die, it requires the development of two distinct phases of aeration in which the optimal conditions are met (aerobic and anoxic) fixed initially.

The results in Table 6 shown in (Fig. 6) represent variation in ion concentrations nitrate NO3-N and phosphate$P\text{-}PO_4^{3-}$ in strict anoxic phase. The concentration of $N\text{-}NO_3^-$ decreased by 29,42mg/l to 2,75mg/l. That of $P\text{-}PO_4^{3-}$ ions increases by 3.78mg/l to 6,33mg/l resulting from the release by heterotrophic aerobic bacteria subjected to stress conditions. This phenomenon is very common in anoxic phase. Note also that a portion of phosphorus is removed with the excess sludge from the settler.

Table 6: denitrification and release of phosphorus in strict anoxia

parameters	buffer tank Output	Output bacterial bed
$N\text{-}NO_3^-$	29,42	2,75
$P\text{-}PO_4^{3-}$	3,78	6,33

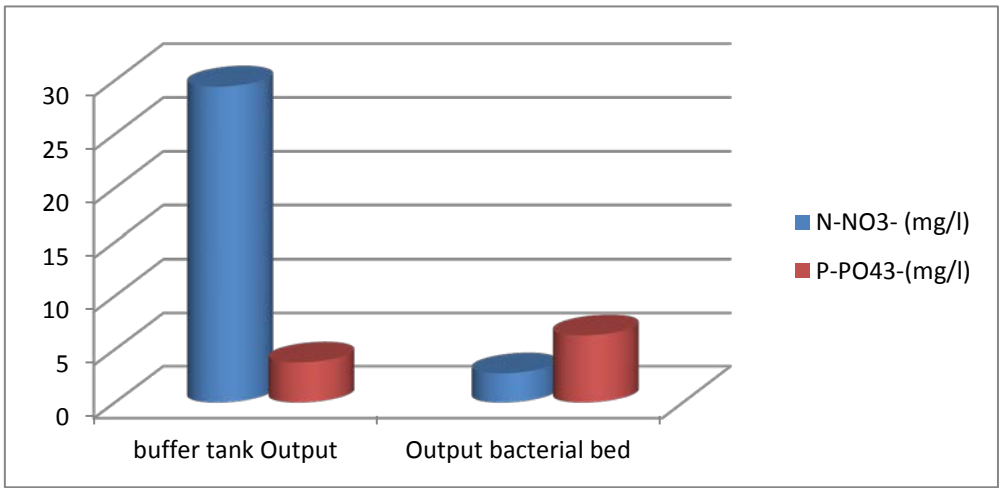


Figure 6: denitrification in bacterial bed in strict anoxia

Overall yield of abatement of total nitrogen and total phosphorus

The overall purification yields of a simultaneous reduction of nitrogen and phosphorus in Table 7 and shown in (Fig. 7) and 8 show the experimental driver performance set up for this purpose, on the coélimination of phosphate and nitrogen pollution of secondary effluent of STEP.

Table 7: simultaneous elimination of nitrogen and phosphate pollution

parameters	Input	Output	yields %
Nt (mg/l)	58.95	6.42	89.10
Pt (mg/l)	13,55	0,75	94,46

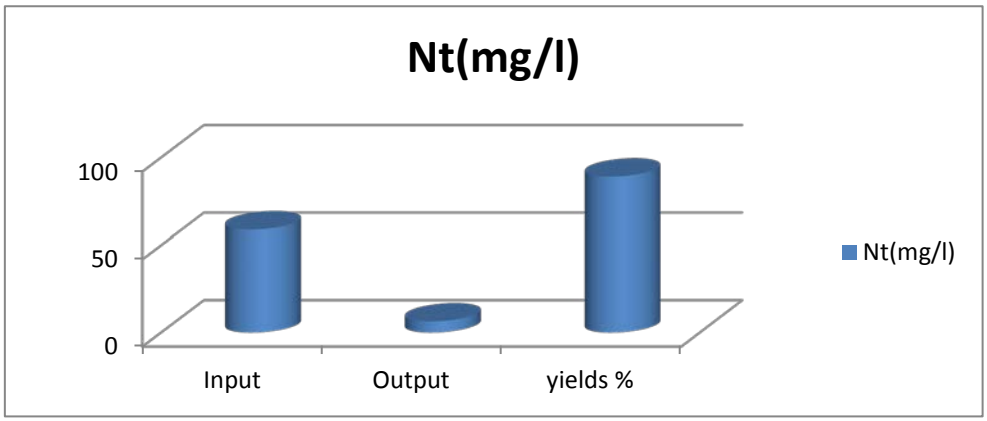


Figure 7: Pilot yields on abatement on reduction of total nitrogen

For the treatment of phosphorus, the only biological contribution provides only part of the total elimination of this element, it does not achieve the quality levels required. For cons, the implementation of biological coupling / physicochemical results in a marked improvement of the treated effluent and removal efficiency compatible with the highest standards. For this, a post-precipitation of phosphate ions is established. The Jar-Test Tests were carried out with the ferric chloride, aluminum sulphate and lime. Ferric chloride was chosen for reasons of cost and performance. A concentration of 40mg/l of ferric chloride (FeCl3) were enough to bring the final total concentration of phosphorus 0.75mg/l, as shown in (Fig. 8).

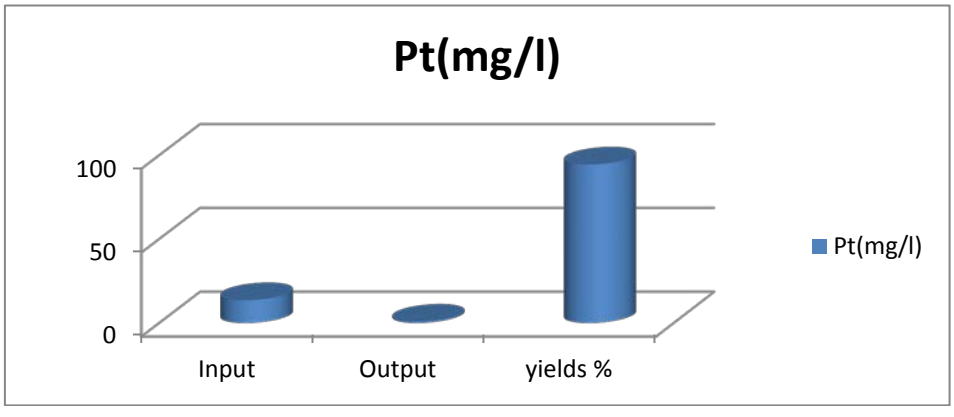


Figure 8: Pilot yields on abatement of total phosphorus

CONCLUSION

The experimental results of this study show that the improved secondary effluent quality parameters and the simultaneous elimination of nitrogen and phosphorus with the driver on biological and physico-chemical mixed reactors, operating with alternating two extreme phases aeration is possible.

The driver allows an improvement in pollution parameters that reach the rate 91.64%, 86.63% and 88.36% for MES, BOD and COD respectively.

The aerobic phase carried out in a free culture activation basin, reveals:

- an important nitrification passing of 1,13mg / l at 43,12mg / l, representing a yield of 96.91%;
- a phosphorus assimilation is observed with decreasing concentration of 11,66mg / l to 3,34mg / l, representing a yield of 71.35%.

The anoxic phase, carried out in a submerged bacterial bed obtained

- significant denitrification that reaches 90.65%;
- a release of phosphorus with a rate of 59.71%.

The conjugation of the different stages of treatment, enables significant abatement of total nitrogen and total phosphorus with returns of 89.10% and 94.46%.

All of the results shows that the values obtained are consistent with the most demanding standards guides. The coupling of biological and physico-chemical treatment provides a comprehensive treatment of the pollution load of secondary effluent of STEP and thus guarantees the protection of natural environments receivers

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