Use of Bewat Natural Coagulants for Phosphorus Precipitation

S. Lloret Salinas, V. Vidal Sanchis
Bachelor of Biological Sciences

V. Mondragón Andreu
Bachelor of Environmental Physics

O. Hernandis Martínez
Bachelor of Chemical Sciences

V. Albelda i Tudó
Bachelor of Chemical Sciences

G. Fayos Miñana
Dr. in Pharmacy. EGEVASA

A. Boluda Ferri
Industrial Technical Engineer

M. Navalón Mollá
Bachelor of Chemical Sciences (2) industrial specialty, GOMSL

This paper describes the results of the LIFE16 ENV/ES/000156 NEWEST project, which validated the use of Bewat natural coagulants derived from plant raw materials in four WWTPs in the Valencia Region, substituting the use of FeCl3 in two WWTPs with urban influent and two WWTPs with urban influent with an industrial component..

KEYWORDS: Nutrients, Ferric chloride, Natural products, Eutrophication, WWTP

Este artículo describe los resultados del proyecto LIFE16 ENV/ES/000156 NEWEST, que validó el uso de coagulantes naturales Bewat derivados de materias primas vegetales en cuatro EDAR de la Comunidad Valenciana, sustituyendo el uso de FeCl3 en dos EDAR con afluente urbano y dos EDAR de afluente urbano con componente industrial.

PALABRAS CLAVE: Nutrientes, Cloruro férrico, Productos naturales, Eutrofización, EDAR

INTRODUCTION

Most WWTPs use chemical precipitation to remove phosphorus. Chemical precipitation or coagulation is a process that destabilizes the charges of colloidal particles by neutralizing the forces that keep them apart by adding chemicals and applying energy through mixing. Chemical precipitation removes insoluble salts by sedimentation, carrying away phosphorus by adding an inorganic coagulant [1].

The most common metallic salts are ferric chloride, ferric sulphate, ferrous chloride and aluminum polychloride. This technology has the following disadvantages:

• Inorganic coagulants are toxic and corrosive and pose a hazard for workers during handling [2].

• The dosing of inorganic coagulants contributes salts, increasing the chloride and/or sulphate values in the treated water, and therefore the conductivity, which can result in non-compliance with the discharge limits and shorten the lifetime of the installations.

• Certain levels of residual iron color the water.

• The chemical precipitation process increases sludge generation, which limits the efficiency and flow rate of the plant used [3].

• The dependence on large-scale industrial processes worldwide leads to constant increases in the price of inorganic precipitation reagents such as ferric chloride or aluminum polychloride, which increases treatment costs.

The eco-innovative technology presented in this work consists of the use of natural organic polymers that are extracted from the bark of the black acacia (Acacia mearnsii) and, after undergoing certain minor chemical modifications, improve the coagulating efficiency compared to other inorganic materials used today, generating many technical, economic and environmental advantages. These include:

• Enhanced coagulating action due to its strongly cationic nature, neutralizing charges and attracting suspended particles [4].

• Does not modify the pH of the aqueous medium and also shows optimum efficiency in a very wide pH range, between 4.5 and 9.

• Does not consume alkalinity from the medium. This means that it always has maximum coagulating efficiency since it does not undergo hydrolysis in aqueous media [5].

• Protects against corrosion of metal parts, because it does not increase the conductivity of the medium.

» Bewat products are suitable for chemical precipitation of phosphorus in WWTPs, demonstrating that natural coagulants are an environmentally sustainable resource

• The product is supplied in liquid medium, ready to dose, without prior dilution.

• It is an environmentally friendly, organic-based polymer. It is non-corrosive and non-toxic, which promotes subsequent biological processes.

This article shows the results after using the Bewat natural coagulant distributed by the company Servyeco, in four WWTPs in the Region of Valencia. To cover the maximum number of possible scenarios, two WWTPs with a completely urban influent (Lloc nou d'en Fenollet WWTP and Benigànim WWTP) and two WWTPs with urban and industrial intake (Ontinyent-Agullent WWTP and Canals-L'Alcudia de Crespins WWTP) were selected.

MATERIAL AND METHODS

The urban WWTPs studied were Lloc nou d'en Fenollet and Benigànim, managed by the company Egevasa. Both receive a completely urban influent, although the Benigànim WWTP occasionally receives discharges from the canning industry (with high conductivity and COD values), which added a new scenario to evaluate the behavior of Bewat products in phosphorus removal [6].

The main characteristics of the Lloc nou d'en Fenollet WWTP are as follows:

• Influent 100 % assimilable to urban load.

• Flow: 125 m3/day.

• Pt limit according to Discharge Authorization (DA) of 4 mgP/l annual average value.

The main characteristics of the Benigànim WWTP are:

• Influent 100 % assimilable to urban load, with occasional discharges from the canning industry.

• Flow: 1,000 m3/day.

• Pt limit according to DA of 2 mgP/l annual average value.

The urban WWTPs with industrial input studied were Ontinyent-Agullent and Canals-L'Alcudia de Crespins, operated by the companies Egevasa and Gomsl, respectively. The Ontinyent-Agullent WWTP is equipped with two-stage treatment (Stage A+ Stage B) and has an urban influent with an industrial component. This WWTP receives a medium industrial load, which makes it a suitable facility for an initial technical-economic assessment. The Canals-L'Alcudia de Crespins WWTP has an influent with a higher load of pollutants (in terms of conductivity, COD and chromium), with recurring discharges from the tanning industry and primary physical-chemical treatment to reduce the load [7].

The main characteristics of the Ontinyent-Agullent WWTP are:

• Urban influent with industrial component.

• Discharge from the textile industry.

• Flow: 20,000 m3/day.

• Pt limit according to DA of 1 mgP/l annual average value.

The main characteristics of the Canals-L´Alcudia de Crespins WWTP are:

- Urban effluent with a significant industrial component (high conductivity and chromium values).
- Discharge from the textile and tanning industry.
- Flow: 5,000 m3/day.
- Pt limit according to DA of 1 mgP/l annual average value.

The Bewat products were dosed based on the fundamental principle of guaranteeing the quality of the discharge from the WWTPs under study at all times and preventing the possible impact of the process on other points in the treatment process from detracting significantly from the results obtained (Figure 1 and 2). The following analyses were carried out during the dosing of the Bewat products:

- Analysis of total phosphorus values three times a week in the influent to the WWTP and in the effluent.
- Weekly analysis of the parameters established in the discharge authorization for each of the WWTPs studied: pH, conductivity, biological oxygen demand (BOD5), chemical oxygen demand (COD) and suspended solids (SS).

RESULTS AND DISCUSSION

The working dose of the Bewat NW3 product during the implementation of the technology at the Lloc nou d'en Fenollet WWTP (10/10/2018-08/10/2019) was 44 mg/l, which achieved compliance with the current Pt discharge limit.

Figures 3 and 4 show the evolution of Pt in the effluent before and after Bewat NW3 dosing, both periods being prior to the entry into force of the discharge authorization registered on 18/09/2020.

In quantitative terms, before Bewat NW3 dosing, the average total

FIGURE 1. Dosing system installed at the Lloc nou d'en Fenollet WWTP

FIGURE 2. Dosing system installed at Ontiyent-Agullent WWTP

phosphorus value in the effluent during the period analyzed was 3.76 mg P/l. After the implementation of the new technology, the average value in the effluent was 2.3 mg P/l. This indicates an average improvement in phosphorus precipitation of 39% after Bewat NW3 dosing.

We can therefore conclude that the Bewat NW3 product allows correct chemical precipitation of phosphorus in the Lloc nou d'en Fenollet WWTP, complying with the discharge limits at a working concentration of 44 mg/l.

In the case of the Benigànim WWTP, the results obtained for the Lloc nou d'en Fenollet WWTP were already available, so less time was required to adjust the Bewat NW3 dosing. Also, starting on 01/09/2020, Bewat MA was dosed to evaluate this other product in the Bewat product line. Dosing of the Bewat product began in the Benigánim WWTP on 31/10/2019 and ended on 01/12/2020. This dosing period can be divided into the following phases:

- From 31/10/2019 to 14/11/2019, a program was started to reduce the dosage of ferric chloride from 40 mg/l ferric chloride to 40 mg/l Bewat NW3.
- From 14/11/2019 to 01/09/2020 only Bewat NW3 was dosed at a dose of 40 mg/l. This dose was increased on an ad hoc basis due to the inflow of discharges into the WWTP.
- From 01/09/2020 to 01/12/2020, Bewat MA was dosed at a concentration of 40 mg/l.

Figure 5 summarizes the results and the different areas of study; the red rectangle indicates the period in which the dose of ferric chloride was reduced, the blue oval, the period of exclusive dosing of Bewat NW3, and the yellow oval, the period of exclusive dosing of Bewat MA.

As shown in Figure 5, during the dosing of Bewat NW3 and Bewat MA, the established total phosphorus limit of 2 mg P/l was achieved. We can conclude that the Bewat NW3 and

» Bewat coagulants make it possible to reduce chloride and iron concentrations in the effluent compared to the use of ferric chloride

FIGURE 3. Pt values before implementation of the new technology without coagulant dosag

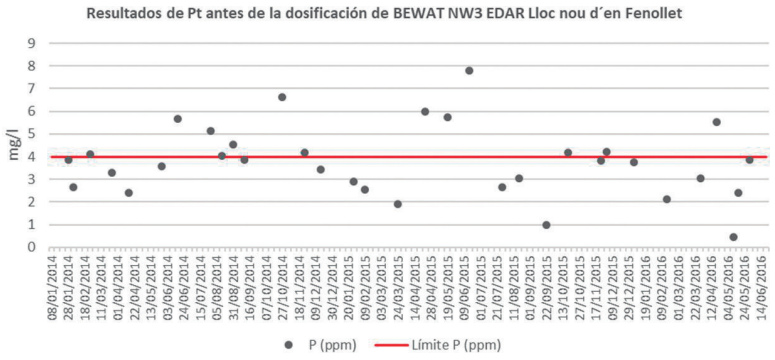


FIGURE 4. Pt values after implementation of the new technology

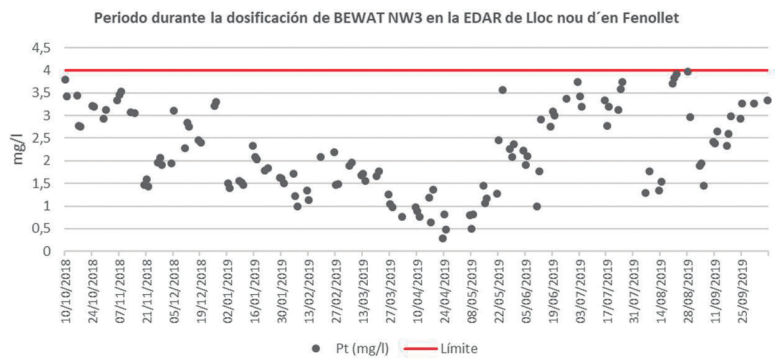
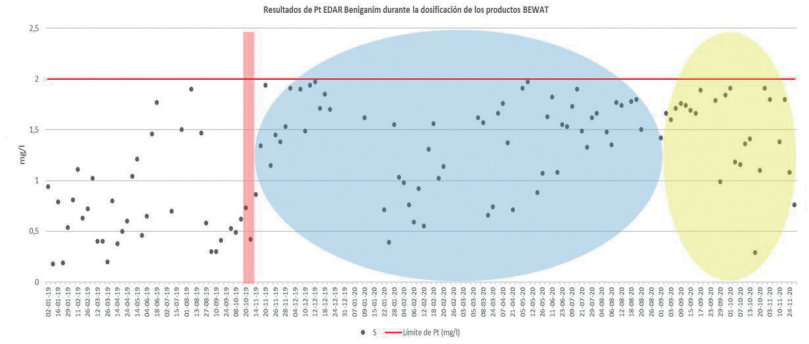


FIGURE 5. Bewat NW3 and Bewat MA dosing period at the Benigànim WWTP



Bewat MA products allowed correct chemical precipitation of phosphorus in the Benigànim WWTP, complying with the discharge limits at a working concentration of 40 mg/l.

Regarding the dosing of Bewat products at the Ontinyent-Agullent WWTP, the process was divided into the following three phases, aimed at a gradually reducing the dose of ferric chloride based on the following premises:

- The first two phases were focused on assessing how ferric chloride and Bewat NW3 work together at different temperatures (average winter temperature of 16 °C and average summer temperature of 24 °C). This is because possible alterations to the biological process (nitrifying and heterotrophic bacteria are affected by temperature) can affect treatment performance (in terms of SS and COD) and thus affect phosphorus removal.
- In the chemical precipitation of phosphorus, part of the ferric chloride used follows the treatment line in the sludge line (facilitating compacting and sedimentation of the sludge) and subsequent anaerobic digestion.

A significant amount of time would be required to evaluate how Bewat NW3 could completely replace the ferric chloride dose in these two aspects because, for example, the hydraulic retention time in anaerobic digestion is usually around 25 days.

These two premises meant that ferric chloride and Bewat NW3 had to be used together for a period of time until the start of phase three (25/09/2019-25/11/2019). The phases would be as follows:

Phase 1 (11/04/2019- 19/06/2019): This period corresponds to winter temperatures in the biological reactor (16ºC). This phase is indicated by the first green oval in Figure 6.

Phase 2 (16/08/2019-11/09/2019). This period corresponds to summer temperatures in the biological reactor (24ºC). This phase is indicated by the second green oval in Figure 6.

Phase 3 (25/09/19-25/11/19). This period corresponds to the period when the ferric chloride was completely replaced by Bewat NW3 based on the positive results obtained in the other two phases. This phase is indicated by the yellow oval in Figure 6.

The red rectangles indicate periods when only ferric chloride was again dosed, in order to compare the different study scenarios and let the system eliminate potential traces of Bewat.

The working doses of the chemicals used during the implementation of the technology are described below:

FIGURE 6. Bewat NW3 dosing period at the Ontinyent-Agullent WWTP

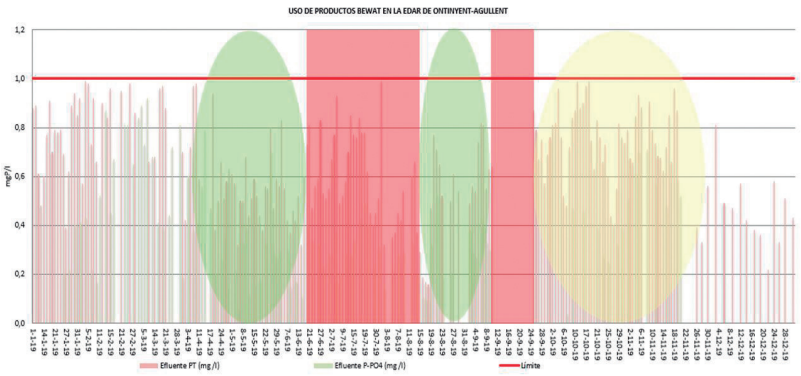


FIGURE 7. Bewat NW3 and Bewat MA dosing period at the Canals-L'Alcudia de Crespins WWTP

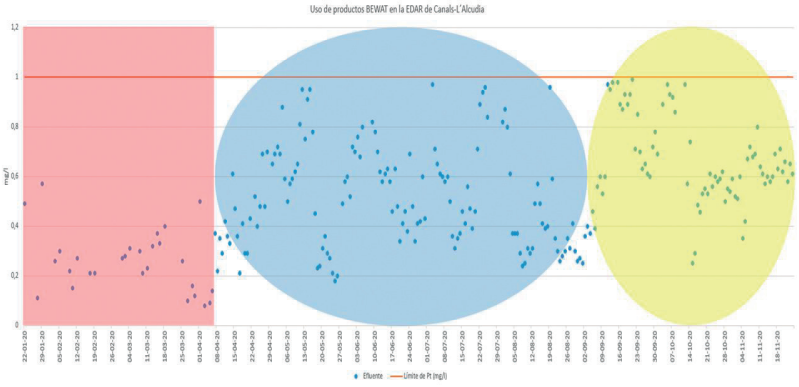
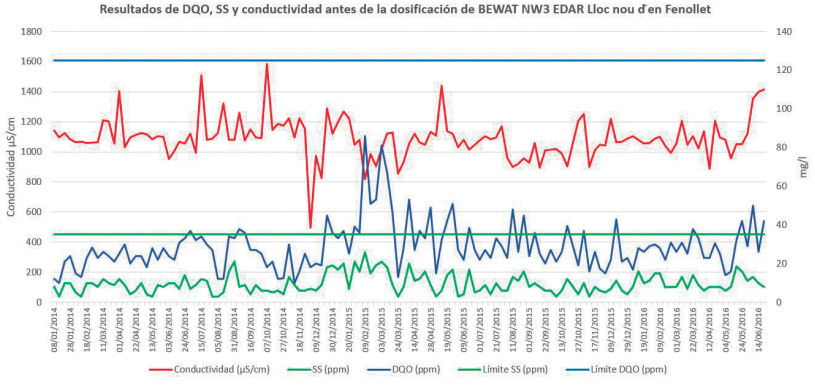


FIGURE 8. Conductivity, SS and COD values before the implementation of the new technology



• Phase 1: During this period, an average concentration of 51 mg/l ferric chloride and 44 mg/l Bewat NW3 was used. This ratio allowed compliance with the maximum Pt value.

• Phase 2: During this period, an average concentration of ferric chloride of 56 mg/l and 83 Bewat NW3 mg/l were used.

• Phase 3: During this period, ferric chloride dosing was completely eliminated and only the Bewat NW3 product was used, and a program to reduce the dosage was carried out, intensifying analytical controls to ensure the quality of the discharge. The reduction program made it possible to reach working concentrations of up to 60 ppm. The use of the study reagent made it possible to completely reduce the dosage of ferric chloride.

We can therefore conclude that the Bewat NW3 product allowed correct chemical precipitation of phosphorus in the Ontinyent-Agullent WWTP, complying with the discharge authorization at a working concentration of 60 mg/l.

Lastly, the dosing of Bewat products at the Canals-L'Alcudia de Crespins WWTP began on 22/01/2020 and ended on 24/11/2020. This period can be divided into the following phases:

• From 22/01/2020 to 06/04/2020, a program to reduce the dosage of ferric chloride from 120 mg/l ferric chloride to 120 mg/l Bewat NW3 was initiated.

• From 06/04/2020 to 01/09/2020, only Bewat NW3 was dosed at a dose of 120 mg/l. This dose was increased occasionally due to the intake of discharges into the WWTP.

• From 01/09/2020 to 24/11/2020, Bewat MA was dosed at a concentration of 120 mg/l.

Figure 7 summarizes the results and the different areas that were studied. The red rectangle refers to the period in which the dose of ferric chloride was reduced, the blue oval to the period of dosing exclusively with Bewat NW3 and the yellow oval to the period of dosing exclusively with Bewat MA.

As shown in Figure 7, during the dosing period, the WWTP complied with the established total phosphorus limit of 1 mg P/l. We can therefore conclude that the Bewat NW3 and Bewat MA products allowed correct chemical precipitation of phosphorus in the Canals-L'Alcudia de Crespins WWTP, complying with the

FIGURE 9. Conductivity, SS and COD values during dosing of Bewat NW3

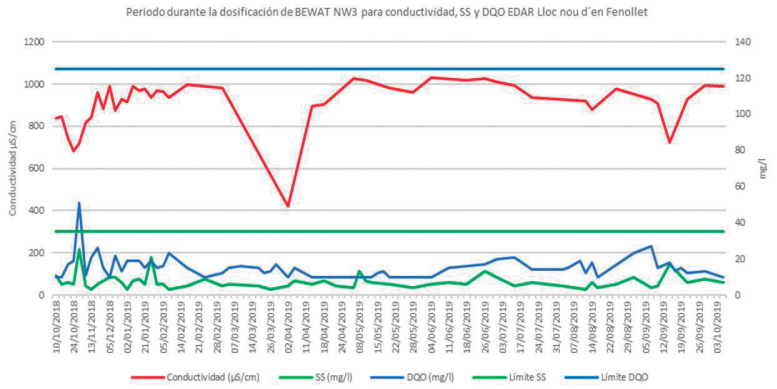


FIGURE 10. Conductivity, SS and COD values before the implementation of the new technology

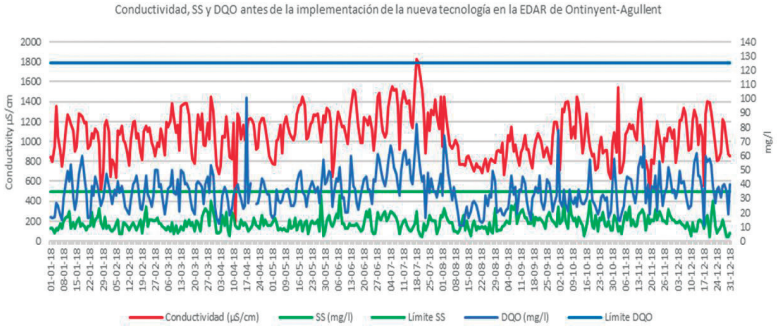


TABLE 1.

AVERAGE PHYSICAL-CHEMICAL VALUES BEFORE AND AFTER THE IMPLEMENTATION OF THE NEW TECHNOLOGY

Average conductivity (µS/cm)	Average conductivity Bewat NW3 (µS/cm)	Average SS (mg/l)	Average SS Bewat NW3 (mg/l)	Average COD (mg/l)	Average COD Bewat NW3 (mg/l)
1,091	917	10	7	29	25

discharge authorization at a working concentration of 120 mg/l.

The dosing of the Bewat range of products is associated with a possible interaction, especially with a whole set of physical-chemical parameters related to wastewater treatment. These parameters were compared with the results obtained in previous years when no coagulant was dosed (Lloc nou d'en Fenollet WWTP) or when ferric chloride was dosed (Ontinyent-Agullent WWTP). The parameters analyzed were: conductivity, suspended solids, chemical oxygen demand, chlorides and iron.

Figure 8 shows the characterization gathered from the log for the parameters of conductivity, SS and COD at the Lloc nou d'en Fenollet WWTP. As shown, during this entire period, the Lloc nou d'en Fenollet WWTP complied with the discharge limits.

Figure 9 shows the values obtained for conductivity, SS and COD parameters during the implementation of the technology.

The discharge authorization for the Lloc nou d'en Fenollet WWTP sets maximum SS values of 35 mg/l and COD of 125 mg/l. As shown in Figure 8 and Figure 9, the WWTP complied with these maximum limits.

Table 1 shows the average values obtained and shows how the best results are obtained by implementing the new technology, based on the dosing of the Bewat NW3 product, significantly improving certain physical and chemical parameters such as conductivity, SS and COD.

Regarding the Ontinyent-Agullent WWTP, the characterization collected during 2018 was analyzed for the parameters of conductivity, SS and COD, as shown in Figure 10. As shown in the figure, throughout 2018, the Ontinyent-Agullent WWTP complied with the limits established in the discharge authorization.

FIGURE 11. Conductivity, SS and COD values during dosing of ECOTAN NW3.

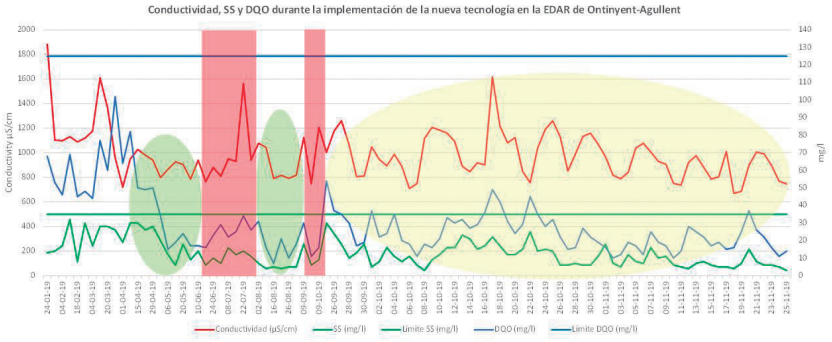


FIGURE 12. Chloride and iron values in the effluent

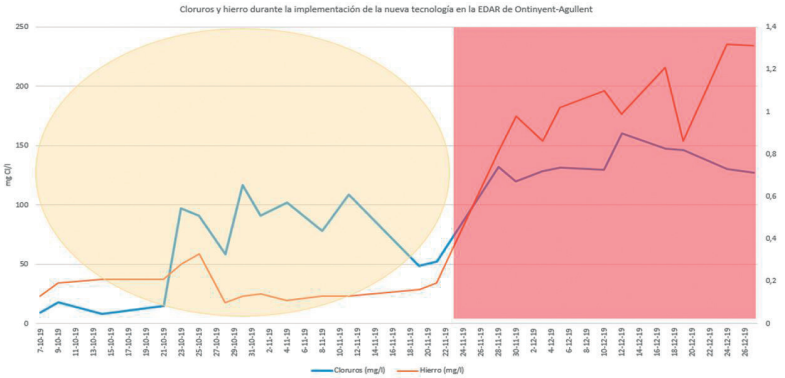


TABLE 2.

AVERAGE PHYSICAL-CHEMICAL VALUES BEFORE AND AFTER THE IMPLEMENTATION OF THE NEW TECHNOLOGY

Average conductivity 2018 (ferric chloride) (µS/cm)	Average conductivity Bewat NW3 (µS/cm)	Average SS 2018 (ferric chloride) (mg/l)	Average SS Bewat NW3 (mg/l)	Average COD 2018 (ferric chloride) (mg/l)	Average COD Bewat NW3 (mg/l)
1,064	968	13	11	35	24

TABLE 3.

AVERAGE CHLORIDE AND IRON VALUES IN THE EFFLUENT

Average chloride value during ferric chloride dosing (mg/l)	Average chloride value during Bewat NW3 dosing (mg/l)	Average dissolved iron value during ferric chloride dosing (mg/l)	Average dissolved iron value during Bewat NW3 dosing (mg/l)
142.22	63.89	1.06	0.18

Figure 11 shows the values obtained for conductivity, SS and COD parameters during the implementation of the technology.

The Discharge Authorization of the Ontinyent-Agullent WWTP sets maximum SS values of 35 mg/l and COD of 125 mg/l. As shown in Figure 11, the WWTP complied with the established maximum values during the entire period that the new technology was implemented.

Table 2 shows that the best results in certain physical-chemical parameters such as conductivity, SS and COD are obtained by implementing the new technology, based on the dosing of the Bewat NW3 product.

Lastly, the chloride and iron values in the effluent of the Ontinyent-Agullent WWTP were analyzed due to the additive effect that ferric chloride can have on these parameters. Figure 12 shows the chloride and iron values for 2019, with the red rectangle indicating the period when only ferric chloride was dosed and the yellow oval when only Bewat NW3 was dosed.

Table 3 summarizes the average values and shows a significant reduction in the measured values of chlorides and iron during the implementation of the new technology, as a result of the total elimination of the use of ferric chloride.

CONCLUSIONS

This study assessed the use of products from Servyeco's Bewat range for the chemical precipitation of phosphorus, both in urban WWTPs without industrial components (Lloc nou d'en Fenollet WWTP and Benigànim WWTP) and in urban WWTPs with industrial components (Ontinyent-Agullent WWTP and Canals-L'Alcudia WWTP) as part of the European LIFE16 ENV/ES/000156 NEWEST project.

The following conclusions were obtained at the Lloc nou d'en Fenollet WWTP and Benigànim WWTP:

- Bewat products are suitable for chemical phosphorus precipitation in urban WWTPs.

- The optimum Bewat product consumption for chemical phosphorus precipitation in this type of WWTP is 40 mg/l to achieve the effluent discharge limit.

- Bewat products significantly improve effluent quality in terms of COD removal performance.

- Bewat products reduce the concentration of chlorides and iron in the effluent compared to the use of ferric chloride. This is of great importance in the case of discharge authorizations with chloride concentration limits.

In the case of the Ontinyent-Agullent and Canals-L'Alcudia de Crespins WWTPs, the following conclusions were reached:

- The Bewat products tested are suitable for chemical phosphorus precipitation in WWTPs with medium and high industrial input in terms of COD, SS, Cr and conductivity.

- The optimal consumption of Bewat products for chemical precipitation of phosphorus in this type of WWTP is 60 mg/l to achieve an effluent discharge limit of less than 1 mg/l for the Ontinyent-Agullent WWTP and 120 mg/l for the Canals-L'Alcudia de Crespins WWTP, where the industrial input is higher.

- These coagulants significantly improve effluent quality in terms of conductivity reduction and SS and COD removal efficiencies.

- Bewat products reduce salt concentrations in the effluent compared to the use of ferric chloride.

» This study assessed the use of products from Servyeco's Bewat range for the chemical precipitation of phosphorus

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