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Removal of Turbidity and Total Suspended Solids Using *Prunus Serotina* and *Mespilus Germanica* Biocoagulants in a River in Apurímac, Peru

Jhon Jhonatan Cárdenas-Acosta[1], Melissa Ccorisoncco-Huachuhuillca[2], Johnny Leandro Saavedra-Camacho[3*], Carlos Eduardo Dueñas-Valcárcel[4], Yakov Felipe Carhuarupay-Molleda[5]

***Abstract* — This study evaluated the efficiency of the natural biocoagulants *Prunus serotina* and *Mespilus germanica* in the removal of turbidity and total suspended solids (TSS) in a river in Apurímac, Peru. A 3×2×2 factorial design was applied, considering three coagulant doses (0,1; 0,5; and 1,0 g/500 mL), two stirring speeds (50 and 150 rpm), and two settling times (30 and 60 min), with three replicates per treatment. Significant reductions were observed, reaching maximum values of 92,71 % in turbidity and 90,92 % in TSS with *M. germanica*, and 90,16 % in turbidity and 88,73 % in TSS with *P. serotina*. Analysis of variance (ANOVA) confirmed that the dose and sedimentation time significantly influenced the removal of turbidity and TSS ($p < 0,05$), while the agitation speed was relevant only for *P. serotina*. These findings demonstrate that seed extracts of *P. serotina* and *M. germanica* represent viable, sustainable, and low-cost alternatives for water treatment in rural Andean communities.**

Keywords: Seed extracts; natural biocoagulants; turbidity removal; total suspended solids; Apurímac.

***Resumen* — Este estudio evaluó la eficiencia de los biocoagulantes naturales *P. serotina* y *M. germanica* en la remoción de turbidez y sólidos suspendidos totales (SST) en un río en Apurímac, Perú. Se aplicó un diseño factorial 3×2×2, considerando tres dosis de biocoagulante (0,1; 0,5 y 1,0 g/500 mL), dos velocidades de agitación (50 y 150 rpm) y dos tiempos de sedimentación (30 y 60 min), con tres repeticiones por tratamiento. Se mostraron reducciones significativas, alcanzando valores máximos de 92,71 % en turbidez y 90,92 % en SST con *M. germanica*, y de 90,16 % en turbidez y 88,73 % en SST con *P. serotina*. El análisis de varianza (ANOVA) confirmó que la dosis y el tiempo de sedimentación influyeron significativamente en la remoción de turbidez y SST ($p < 0,05$), mientras que la velocidad de agitación resultó relevante únicamente en *P. serotina*. Estos hallazgos evidencian que los extractos de semillas de *P. serotina* y *M. germanica* constituyen alternativas viables, sostenibles y de bajo costo para el tratamiento de aguas en comunidades rurales andinas.**

Palabras Clave: Extractos de semillas; biocoagulantes naturales; turbidez; sólidos suspendidos totales; Apurímac.

I. INTRODUCTION

POLLUTION of surface water sources is one of the main environmental and public health challenges in developing countries. Parameters such as turbidity and total suspended solids (TSS) affect the potability of water resources and generate negative impacts on aquatic ecosystems [1]. In the Chumbao River micro-basin, located in the province of Andahuaylas (Apurímac, Peru), previous studies have reported significant increases in turbidity and solids, associated with urban, agricultural, and mining discharges [2], [3].

The search for sustainable and accessible water treatment technologies has driven the study of plant-based biocoagulants, which are presented as alternatives to chemical coagulants such as aluminum sulfate. These biocoagulants are not only effective in removing turbidity and suspended solids but are also low-cost, non-toxic, and biodegradable [1]. Research with closely related species has reported promising results: seeds of *Prunus persica* (peach) and *Persea americana* (avocado) achieved turbidity removal rates exceeding 80 % in surface waters [4], [5]. Similarly, *Moringa oleifera* and *Echinopsis peruviana* showed

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* *Corresponding author:* johnnylsc107@gmail.com
1. Jhon Jhonatan Cárdenas-Acosta is with the Facultad de Ingeniería, Universidad Nacional José María Arguedas, Jr. Juan F. Ramos, Andahuaylas, Peru. E-mail: jonathancardenasacosta@gmail.com. ORCID number https://orcid.org/0009-0004-4869-3827.
2. Melissa Ccorisoncco-Huachuhuillca is with Facultad de Ingeniería, Universidad Nacional José María Arguedas, Jr. Juan F. Ramos, Andahuaylas, Peru. E-mail: melissaccorisonccoh@gmail.com. ORCID number https://orcid.org/0000-0001-7873-3843.
3. Johnny Leandro Saavedra-Camacho is with the Facultad de Ciencias Biológicas, Universidad Nacional Pedro Ruiz Gallo, Calle Juan XXIII 391, Lambayeque, Peru. E-mail: johnnylsc107@gmail.com. ORCID number https://orcid.org/0000-0002-3842-4314.
4. Carlos Eduardo Dueñas-Valcárcel is with the Facultad de Ingeniería, Universidad Nacional José María Arguedas, Jr. Juan F. Ramos, Andahuaylas, Peru. E-mail: cduenasv@unsa.edu.pe. ORCID number https://orcid.org/0000-0002-1141-6218.
5. Yakov Felipe Carhuarupay-Molleda is with the Facultad de Ingeniería, Universidad Nacional José María Arguedas, Jr. Juan F. Ramos, Andahuaylas, Peru. E-mail: yakov_cc@hotmail.com. ORCID number https://orcid.org/0000-0001-6467-677X.

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efficiencies comparable to synthetic coagulants, with the advantage of being biodegradable and less toxic [6], [7].

In this context, seed extracts from *P. serotina* and *M. germanica* represent an opportunity for innovation, as their application as biocoagulants has been scarcely documented in the scientific literature. Ethnobotanical studies indicate that *P. serotina* contains tannins and flavonoids with coagulant properties [8], while research on *M. germanica* shows a high polyphenol content with potential for water clarification [9]. These chemical characteristics suggest their effectiveness in removing turbidity and suspended solids, although experimental studies are still needed to validate their performance under local conditions. Therefore, the objective of this research was to evaluate the removal capacity of turbidity and TSS using seed extracts of *P. serotina* and *M. germanica* in the waters of the Chumbao River microbasin, Andahuaylas, Apurímac, in 2024, determining the optimal conditions of dosage, agitation speed, and sedimentation time.

II. MATERIAL AND METHODS

This study was applied in nature, with a descriptive and experimental scope, since variables were manipulated under controlled conditions to observe their effects on water quality, without intending to establish theoretical generalizations.

Water samples were collected from the Chumbao River at the Chihuampata intake (Andahuaylas, Apurímac), following the National Protocol for Monitoring the Quality of Surface Water Resources. Twenty-two liters of water were obtained, stored in clean plastic containers, and transported to the laboratory. The initial parameters were turbidity (111,7 NTU) and TSS (639 mg/500 mL).

The biocoagulants were obtained from the seeds of *P. serotina* and *M. germanica*. The seeds were collected, sun-dried for one month, ground, and defatted using Soxhlet extraction with hexane. They were then oven-dried at 105 °C, crushed, and sieved to obtain a fine powder, which was used as a biocoagulant in the experimental treatments.

The experimental design was a 3×2×2 factorial design, considering three factors:

- Biocoagulant dosage: 0,1 g/500 mL, 0,5 g/500 mL, and 1,0 g/500 mL.
- Sedimentation time: 30 min and 60 min.

Stirring speed: 50 rpm and 150 rpm.

This resulted in a total of 12 treatments, each with three repetitions, corresponding to 36 experimental units per biocoagulant.

Jar tests were performed in 500 mL volumes. Rapid stirring was applied for 2 minutes, followed by slow stirring for 5 minutes. The samples were then allowed to settle according to the corresponding sedimentation time. Subsequently, turbidity was measured using a HACH 2100Q turbidimeter, and TSS were measured by filtration and gravimetric weighing.

For statistical analysis, a three-way factorial ANOVA was applied, considering turbidity and TSS as dependent variables, and dose, sedimentation time, and agitation speed as factors. Prior to the analysis, the assumptions of normality (Shapiro-Wilk test) and homogeneity of variances (Levene's test) were verified. When significant differences were detected ($p < 0,05$), Tukey's post-hoc test was applied to identify differences between treatments. Statistical processing was performed using SPSS (v.25) and Excel 2019.

III. RESULTS

A. Initial characterization of the water

The surface water samples collected from the Chumbao River showed an initial turbidity of 111,7 NTU and a TSS concentration of approximately 1 278 mg/L. These values were considered as a reference to evaluate the efficiency of *P. serotina* and *M. germanica* seed extracts in removing these parameters (Table I).

TABLE I
INITIAL CHARACTERIZATION
OF THE WATER OF THE CHUMBAO RIVER

Parameters	Initial value	Unit
Turbidity	111,7	NTU
TSS	639	mg/L

B. Verification of statistical assumptions

Prior to the analysis of variance, the Shapiro-Wilk normality test and Levene's test for homogeneity of variances were applied. No significant deviations from normality were observed with the *M. germanica* extract ($p > 0,05$), while a slight deviation was detected in *P. serotina* ($p < 0,05$); however, the Q-Q plots showed an acceptable fit. In both cases, Levene's test confirmed homogeneity of variances ($p > 0,05$). Therefore, it was considered valid to apply factorial ANOVA to evaluate the effects of dose, time, and agitation speed on removal efficiency. Graphical evidence of the verification of assumptions is presented in the Annexes (Figures A1–A8).

C. Turbidity removal

All treatments exceeded 75 % efficiency. The best results were achieved with 0,1 g/500 mL and 60 min of sedimentation. *Note:* Bars represent mean ± standard deviation (n = 3). Different letters above the bars indicate significant differences (Tukey, $p < 0,05$) (Table II; Fig. 1):

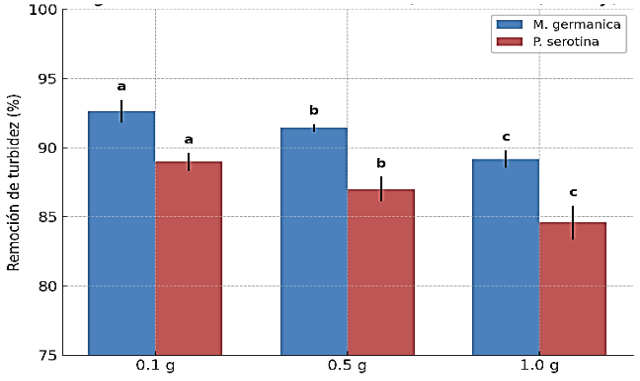

Fig. 1. Turbidity removal with *M. germanica* and *P. serotina*.

TABLE II
TURBIDITY REMOVAL BY TREATMENT

Biocoagulant	Dose (g/500 mL)	Time (min)	RPM	Turbidity (%)	Tukey
M. germanica	0,1	60	50	92,62 ± 0,83	A
M. germanica	0,5	60	50	91,43 ± 0,28	B
M. germanica	1,0	60	50	89,17 ± 0,64	C
P. serotina	0,1	60	50	88,97 ± 0,64	A
P. serotina	0,5	60	50	87,01 ± 0,89	B
P. serotina	1,0	60	50	84,60 ± 1,21	C

In both biocoagulants, the trend was clear: 0,1 g > 0,5 g > 1,0 g. The 60 min sedimentation time was more effective than 30 min under all conditions, and in *P. serotina* the stirring speed also influenced the results, showing better performance at 50 rpm. In *P. serotina*, all three factors (dose, rpm, and time) had a significant influence ($p < 0,05$) (Table III). In *M. germanica*, dose ($p = 0,000$) and time ($p = 0,000$) were significant, while speed was not ($p = 0,663$) (Table IV).

TABLE III
ANALYSIS OF VARIANCE (ANOVA) OF TURBIDITY IN *P. SEROTINA*

SV	DF	SC	MC	F value	P value
Biocoagulant dosage	2	69,69	34 847	14,13	0,000
Stirring speed	1	31,54	31 544	12,79	0,001
Sedimentation time	1	35,73	35 732	14,49	0,001
Error	31	76,43	2 466		
Pure error	24	55,56	2 315		
Total	35	213,40			

TABLE IV
ANALYSIS OF VARIANCE (ANOVA)
OF TURBIDITY IN *M. GERMANICA*

SV	DF	SC	MC	F value	P value
Biocoagulant dosage	2	33 056	16 528	10,14	0,000
Stirring speed	1	0,315	0 315	0,19	0,663
Sedimentation time	1	49 419	49 419	30,32	0,000
Error	31	50 523	1 630		
Pure error	24	42 577	1 774		
Total	35	133 313			

D. Removal of TSS

The highest values were also recorded with 0,1 g/500 mL and 60 min, reaching: *M. germanica*: 90,42 ± 0,54 % (50 rpm); *P. serotina*: 88,16 ± 1,26 % (50 rpm). Bars represent mean ± standard deviation (n = 3). Different letters above the bars indicate significant differences (Tukey, $p < 0,05$) (Table V; Fig. 2).

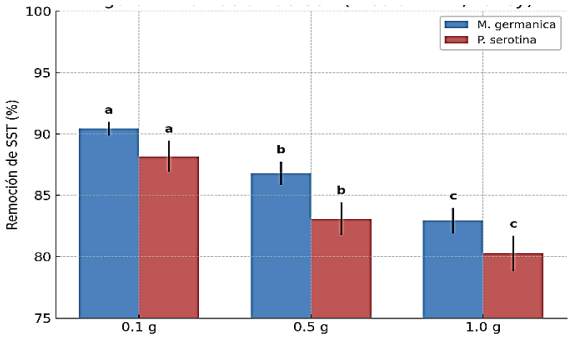

Fig. 2. Removal of SST with M. *germanica* and *P. serotina*.

TABLE V
SST REMOVAL BY TREATMENT

Biocoagulant	Dose (g/500 mL)	Time (min)	RPM	Turbidity (%)	Tukey
M. germanica	0,1	60	50	90,42 ± 0,54	A
M. germanica	0,5	60	50	86,80 ± 0,95	B
M. germanica	1,0	60	50	82,93 ± 1,04	C
P. serotina	0,1	60	50	88,16 ± 1,26	A
P. serotina	0,5	60	50	83,09 ± 1,32	B
P. serotina	1,0	60	50	80,27 ± 1,44	C

In both cases, the 0,1 g dose was more effective than 0,5 g and 1,0 g. In *P. serotina*, the 60 min time significantly improved efficiency, while in *M. germanica*, time and speed had no relevant effects. In *P. serotina*, the dose ($p = 0,000$) and time ($p = 0,015$) were significant, while the rate was not ($p = 0,471$) (Table VI). In *M. germanica*, only the dose was significant ($p = 0,000$) (Table VII).

TABLE VI
ANALYSIS OF VARIANCE (ANOVA) OF SST FOR *P. SEROTINA*

SV	DF	SC	MC	F value	P value
P. serotina biocoagulant dosage	2	349,311	174,655	24,93	0,000
Stirring speed	1	3,729	3,729	0,53	0,471
Sedimentation time	1	46,747	46,747	6,67	0,015
Error	31	217,199	7,006		
Pure error	24	188,676	7,861		
Total	35	616,986			

TABLE VII
ANALYSIS OF VARIANCE (ANOVA) OF SST FOR *M. GERMANICA*

SV	DF	SC	MC	F value	P value
Biocoagulant dosage	2	379,01	189,504	19,05	0,000
Stirring speed	1	25,63	25,630	2,58	0,119
Sedimentation time	1	15,32	15,323	1,54	0,224
Error	31	308,36	9,947		
Pure error	24	272,16	11,340		
Total	35	728,32			

The points follow the diagonal, indicating fit to normality (Shapiro-Wilk: *M. germanica*, p = 0,921; *P. serotina*, p = 0,00016) (Fig. 3 and Fig. 4).

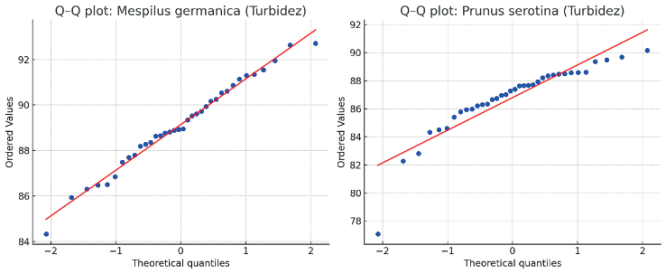

Fig. 3. Q-Q plot of residues for turbidity removal with *M. germanica*.

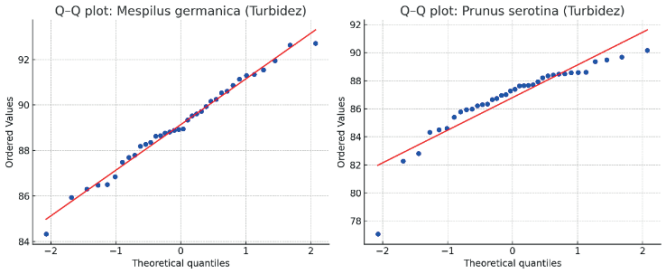

Fig. 4. Q-Q plot of residues for turbidity removal with *P. serotina*.

In *M. germanica*, a slight deviation is observed (p = 0,005), while in *P. serotina* the data are adjusted to normality (p = 0,125) (Fig. 5 and Fig. 6).

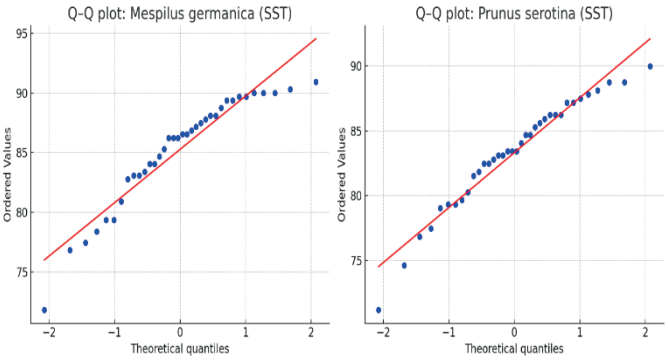

Fig. 5. Q-Q plot of residues for SST removal with M. germanica and P. serotina.

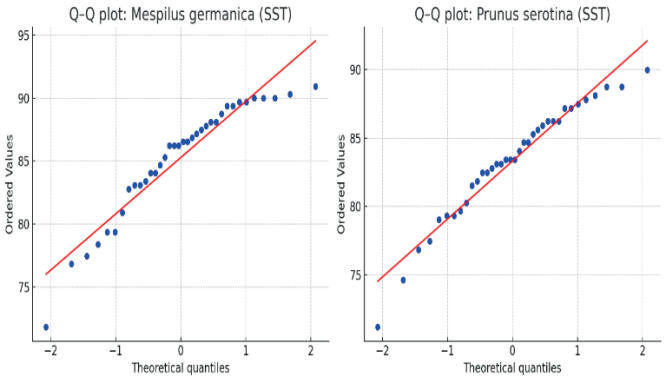

Fig. 6. Q–Q plot of residues for SST removal with *M. germanica* and *P. serotina*.

The similarity in dispersion between groups confirms homogeneity of variances (Levene, p = 0,708) (Fig. 7).

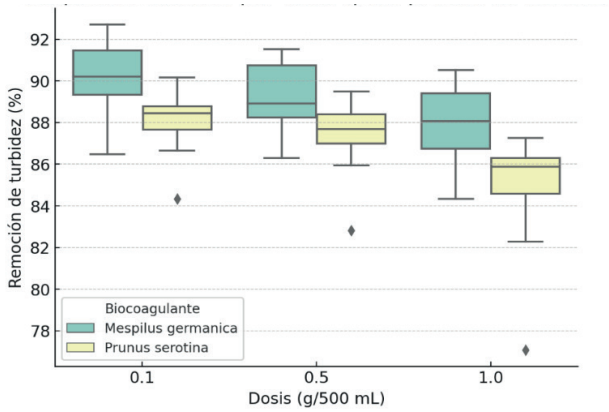

Fig. 7. Boxplot of turbidity by dose for *M. germanica* and *P. serotina*.

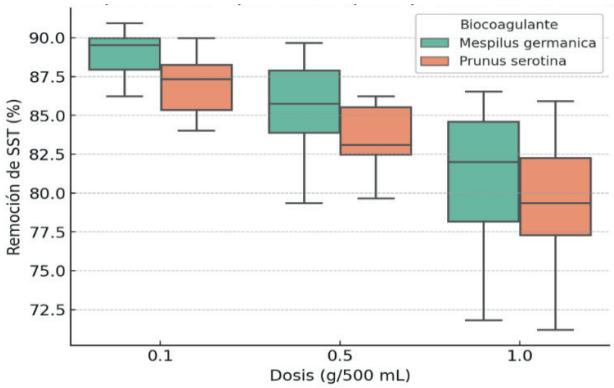

Fig. 8. Boxplot of SST by dose for *M. germanica* and *P. serotina*.

The dispersion is comparable between treatments, confirming homogeneity of variances (Levene, p = 0,752) (Fig. 8).

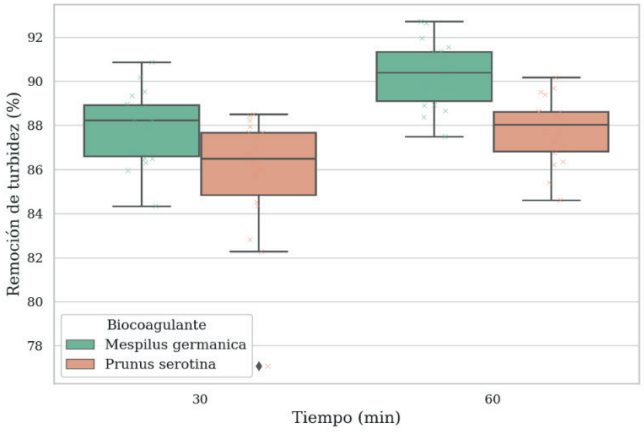

Fig. 9. Boxplot of turbidity by sedimentation time for *M. germanica* and *P. serotina*.

At 60 min, greater removal was achieved compared to 30 min, confirming the influence of time (ANOVA, p < 0,05) (Fig. 9).

In *P. serotina,* a significant difference was observed between 50 and 150 rpm, while in *M. germanica* no relevant changes were observed (Fig. 10).

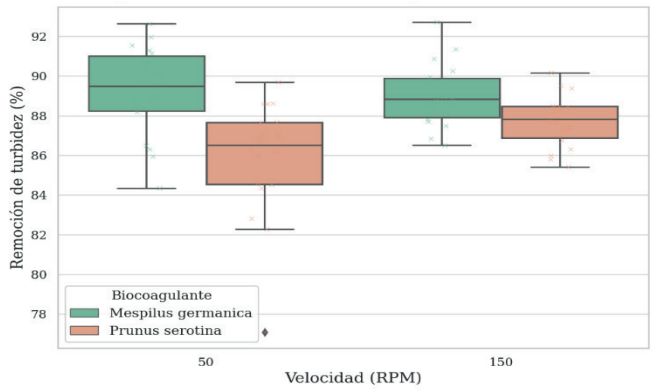

Fig. 10. Boxplot of turbidity by agitation speed for *M. germanica* and *P. serotina.*

The 60 min sedimentation time improved efficiency in *P. serotina* (p = 0,015), while in *M. germanica* it had no statistically significant effect (Fig. 11).

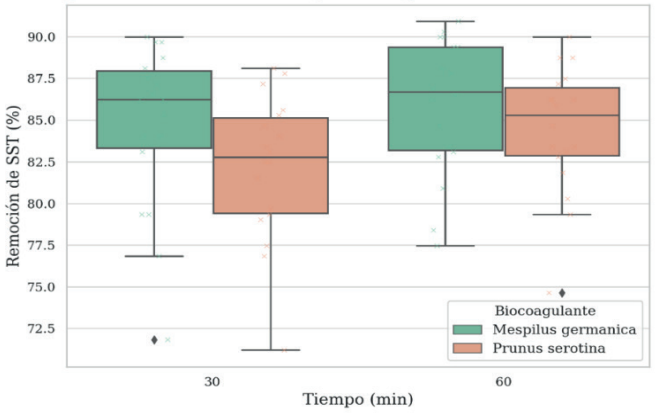

Fig. 11. Boxplot of SST by sedimentation time for *M. germanica* and *P. serotina.*

The agitation speed showed no significant differences in the removal of TSS in any of the biocoagulants (Fig. 12).

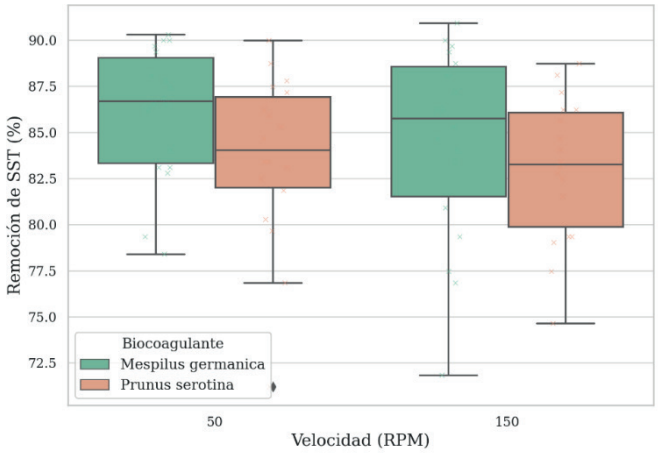

Fig. 12. Boxplot of SST by agitation speed for *M. germanica* and *P. serotina.*

IV. DISCUSSION

This study demonstrates that seed extracts from *P. serotina* (capulí) and *M. germanica* (medlar) are promising alternatives for the removal of turbidity and TSS in surface waters of the Chumbao River micro-basin. Under the applied experimental conditions, both biocoagulants achieved high efficiencies (≈88-93 % under optimal conditions), values comparable to those reported in studies with *M. oleifera* and other widely documented plant coagulants, which achieve between 80 % and 98 % turbidity removal in surface waters [10], [12]. Similarly, comparable results have been described in related species such as *P. persica* and *P. americana*, with efficiencies exceeding 80 % [4], [5]. Thus, it is confirmed that the evaluated biocoagulants possess potential comparable to that of conventional chemical coagulants, but with the advantage of being biodegradable and having a lower environmental impact [13].

The observed mechanism of action is explained by the presence of phenolic compounds, cationic proteins, and tannins that promote charge neutralization and the formation of stable flocs. [14] demonstrated that the cationic proteins of *Moringa oleifera* act as the main coagulating agents, while [8] showed that the tannins of *P. serotina* contribute to the precipitation of colloidal particles and organic matter. This explains the high efficiency of *P. serotina* in turbidity reduction. On the other hand, studies such as [9] documented the effectiveness of *M. germanica* in reducing TSS in wastewater, which supports the slight superiority found in this biocoagulant compared to capulí in the present study.

Among the operational factors evaluated, dosage was the determining factor. The 0,1 g/500 mL dose achieved the highest efficiencies, while higher doses (0,5 and 1,0 g/500 mL) reduced performance. This effect is due to overdosing, a phenomenon in which an excess of coagulant causes particle re-stabilization, reducing efficiency, as described in several studies [5], [6], [15]. This finding is particularly relevant in rural communities, as it demonstrates that low doses can be sufficient to achieve high removal levels, reducing costs and simplifying operations.

Sedimentation time was another critical factor. The best results were obtained with 60 minutes, while 30 minutes yielded lower efficiency. This is explained by the fact that denser and more stable flocs require a longer time to settle completely. This coincides with the findings of [16], who observed that natural coagulants based on tannins require adequate settling periods to consolidate the clarification process.

Agitation speed showed differentiated effects: in *P. serotina*, moderate agitation (50 rpm) favored the formation of more stable flocs, while more intense agitation (150 rpm) reduced efficiency, probably due to aggregate breakup. In *M. germanica*, however, no significant differences were observed, indicating that its bioactive compounds can maintain floc stability over a wider range of hydrodynamic conditions. This behavior has been reported in studies of natural coagulants, where moderate agitation is preferred to avoid floc dispersion [16], [17].

From a statistical perspective, the verification of the assumptions of normality (Shapiro-Wilk) and homogeneity of variances (Levene) confirmed the validity of using factorial ANOVA. In *M. germanica*, both dose and time were signifi-

cant ($p < 0,05$), while speed was not; in *P. serotina*, all three factors (dose, time, and speed) were significant ($p < 0,05$). The use of Tukey's test also allowed for clear differentiation of the treatments, showing that low doses and long times were statistically superior, results consistent with those recommended in similar studies [18], [19].

These findings have practical implications. The turbidity and TSS levels achieved after treatment approach or meet the Environmental Quality Standards for Water in Peru [20], which supports their applicability for improving the quality of drinking water after complementary purification processes. Furthermore, as low-cost, biodegradable, and readily available products in the Andean region, *Prunus serotina* and *Mespilus germanica* align with the principles of sustainability, technological sovereignty, and the Sustainable Development Goals, especially SDG 6: Clean Water and Sanitation [21].

However, certain limitations must be considered: the trials were conducted at laboratory scale, so pilot tests under real operating conditions are recommended to validate their effectiveness. Furthermore, future studies should include advanced chemical analyses (FTIR, chromatography, electrophoresis) to identify the compounds responsible for the coagulant activity and optimize their extraction [13]. Similarly, the management of the generated sludge requires attention because, although it is less toxic than that produced by chemical coagulants, its final disposal or potential agricultural use should be evaluated within circular economy strategies [18].

Taken together, this research provides evidence that extracts of *Mespilus germanica* and *Prunus serotina* are not only technically effective but also constitute an environmentally friendly, culturally relevant, and economically viable solution for water treatment in rural contexts of the Peruvian Andes. The local availability of these species in Apurímac reinforces their potential for community implementation, integrating traditional knowledge with scientific innovation to address the challenges of sustainable water management.

V. CONCLUSION

In conclusion, both biocoagulants, *P. serotina* and *M. germanica*, are highly effective for removing turbidity and TSS, exceeding 70 % efficiency in all treatments performed. This highlights the importance and impact of both biological products on river water pollution. It is worth noting that, although the main limitation of this study is that it was conducted only at the laboratory level, it provides significant evidence for future research and for the developing of policies aimed at reducing pollution through the use of natural resources.

Therefore, it is suggested to continue studying biocoagulants as an alternative for the removal of turbidity from the various aquatic resources of Peru.

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