Research paper **P 5**

REMOVAL OF MALATHION FROM WATER USING CARBON-BASED ADSORBENTS PREPARED FROM RABBIT LITTER WASTE

T. Terzić[1], V. Milanković[1], N. Radivojević[1], J. Krstić[2], A. Jocić[1], S. Gutić[3], V. Anićijević[4], S. Brković[1], I. Pašti[5] and T. Lazarević-Pašti[1]

[1]*Vinča Institute of Nuclear Sciences – National Institute of the Republic of Serbia, University of Belgrade, Mike Petrovića Alasa 12-14, 11351 Belgrade, Serbia*

[2]*University of Belgrade, Institute of Chemistry, Technology and Metallurgy, National Institute of the Republic of Serbia, Njegoševa 12, 11000 Belgrade, Serbia*

[3]*Faculty of Science - University of Sarajevo, Zmaja od Bosne 33-35, Sarajevo 71000, Bosnia and Herzegovina (sgutic@pmf.unsa.ba)*

[4]*Military Academy, University of Defence in Belgrade, Veljka Lukica Kurjaka 33, 11042 Belgrade, Serbia*

[5]*University of Belgrade – Faculty of Physical Chemistry, Studentski Trg 12–16, 11158 Belgrade, Serbia*

DOI: 10.68725/FDSQ_WORKSHOP.2026.9.16

ABSTRACT

The presence of organophosphate pesticides in water represents an important environmental concern due to their toxicity and possible transfer through the food chain. This study investigates carbon-based adsorbents prepared from rabbit litter waste for the removal of malathion (MLT) from water. The waste biomass was chemically impregnated and carbonized at 900 °C. The prepared adsorbents were characterized by SEM and BET analysis, while MLT adsorption was evaluated through batch experiments and quantified by UPLC. Adsorption equilibrium was reached within 30 min, and the maximum adsorption capacities were 17.66 and 27.52 mg g^{-1}, depending on the chemical treatment applied. The results suggest that rabbit litter waste can be valorized into efficient adsorbents for the treatment of pesticide-contaminated water.

INTRODUCTION

Malathion is a widely used organophosphate pesticide, and its extensive use in crop protection raises environmental and public health concerns due to its toxicity, mobility, and potential to persist in soil and water systems [1]. Among available methods for pesticide removal, adsorption is an efficient and environmentally friendly strategy. Carbon-based adsorbents are particularly

promising due to their porous structure, high surface area, and favorable surface chemistry [2]. In this study, rabbit litter waste was converted into carbon-based adsorbents and evaluated as a sustainable material for MLT removal from water, thereby supporting waste valorization and contributing to the remediation of pesticide-contaminated water in the context of food and environmental safety.

EXPERIMENTAL

Rabbit litter waste (rabbit sawdust containing urine) was used as a precursor for carbon-based adsorbents. The biomass was impregnated with either H_3PO_4 or NaOH, yielding CRL_H and CRL_N, respectively, and carbonized in a tube furnace under nitrogen flow (100 L h^{-1}) at 900 °C for 60 min, with a heating rate of 5 °C min^{-1}. The prepared materials were characterized by SEM. Nitrogen adsorption measurements were performed at 77 K using a Sorptomatic 1990 analyzer after degassing at 200 °C for 24 h, and the specific surface area was calculated using the BET method. MLT adsorption experiments were performed as previously described [2].

RESULTS AND DISCUSSION

The SEM micrographs (Figure 1) reveal an irregular, layered carbonaceous morphology with visible surface roughness and cracks, suggesting structural changes induced by carbonization and chemical treatment. Such a morphology may contribute to the accessibility of adsorption sites involved in MLT removal.

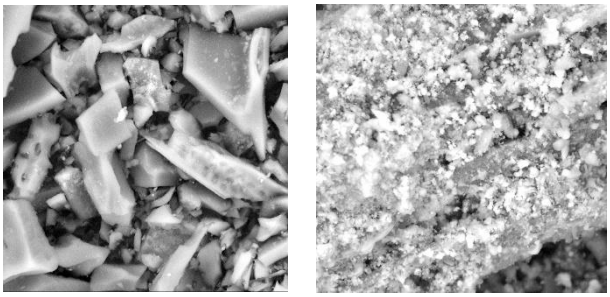


Figure 1. SEM micrographs of CRL_H (left) and CRL_N (right) materials

The specific surface area of the prepared materials, determined by the BET method, was significantly higher for CRL_H (419 m^2 g^{-1}) than for CRL_N (109 m^2 g^{-1}), indicating that H_3PO_4 impregnation was far more effective in developing the material's surface area.

The equilibrium contact time was determined by monitoring the residual MLT concentration in solution after contact with the adsorbent materials. The results, presented in Figure 2, showed that the MLT concentration reached a nearly constant value after 30 min, which was selected as the equilibrium contact time for further adsorption experiments.

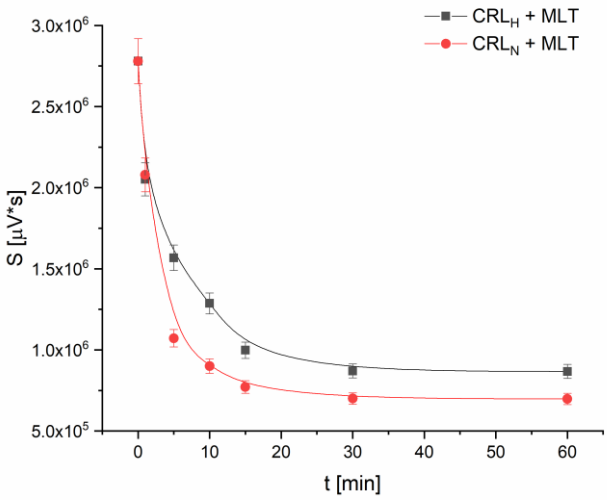


Figure 2. Determination of equilibrium contact time.

Adsorption isotherms were analyzed using the non-linear Freundlich and Langmuir models to evaluate MLT adsorption behavior and adsorbent affinity (Table 1). The Freundlich model provided a very good fit to the experimental data for both materials, with n values higher than 1, indicating favorable adsorption on energetically heterogeneous surfaces. The higher K_F value obtained for CRL_N suggests a stronger affinity of MLT toward this material than toward CRL_H. Although the Langmuir model also provided an acceptable fit, its assumption of monolayer adsorption on a homogeneous surface should be used with caution. Therefore, the Langmuir q_{max} values are primarily used for comparison between the two materials, rather than as absolute maximum adsorption capacities. The higher q_{max} value obtained for CRL_N (27.52 mg g^{-1}) compared to CRL_H (17.66 mg g^{-1}) follows the same trend as the Freundlich model and indicates better adsorption performance of CRL_N. This improvement may be attributed to the favorable influence of NaOH impregnation on surface chemistry and the accessibility of adsorption sites. However, the results also suggest that a developed specific surface area alone is not necessarily sufficient for efficient MLT adsorption, most likely due to incomplete surface accessibility and the specific interaction requirements of MLT molecules.

Table 1. Parameters of the Freundlich and Langmuir isotherm models for MLT adsorption at an adsorbent dose of 1 mg mL^{-1}

Material	Freundlich isotherm			
	K_F ($(dm^3\ mg^{-1})^{1/n}$)	n	χ^2	R^2
CRL_H	0.165	1.321	0.173	0.980
CRL_N	0.264	1.321	0.050	0.998
	Langmuir isotherm			
	K_L ($dm^3\ mg^{-1}$)	q_{max} ($mg\ g^{-1}$)	χ^2	R^2
CRL_H	0.005	17.661	0.225	0.975
CRL_N	0.005	27.519	0.145	0.993

CONCLUSION

Rabbit litter waste was successfully converted into carbon-based adsorbents for the removal of MLT from water. Although CRL_H showed a higher specific surface area, CRL_N exhibited better adsorption performance, indicating the important role of surface chemistry and accessible adsorption sites. The results highlight rabbit litter waste as a promising precursor for sustainable adsorbents in pesticide-contaminated water treatment.

Acknowledgement

This work was funded by the Serbian Ministry of Science, Technological Development, and Innovations (grant numbers 451-03-34/2026-03/200146, 451-03-33/2026-03/200017, and 451-03-33/2026-03/200026). The authors also acknowledge support from the Serbian Academy of Sciences and Arts (project no. F-49). The authors also acknowledge the support provided by the Serbian Ministry of Defence, Republic of Serbia (project code: VA-TT/1/22-24).

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