

Evaluation of Antimicrobial Activity, Hemostatic Efficacy, Blood Coagulation Dynamics, and DNA Damage of Linen–Copper Composite Materials

Zdzisława Mrozińska ¹, Małgorzata Świerczyńska ^{1,2}, Michał Juszcak ^{1,3}, Katarzyna Woźniak ³ and Marcin H. Kudzin ^{1,*}

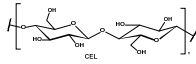
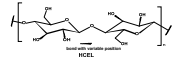
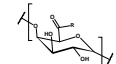
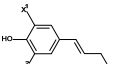
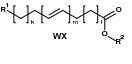
¹ Łukasiewicz Research Network—Lodz Institute of Technology, Marii Skłodowskiej-Curie 19/27, 90-570 Lodz, Poland

² Institute of Polymer and Dye Technology, Faculty of Chemistry, Lodz University of Technology, Stefanowskiego 16, 90-537 Lodz, Poland

³ Department of Molecular Genetics, Faculty of Biology and Environmental Protection, University of Lodz, Lodz, 90-236, Pomorska 141/143, 90-236 Lodz, Poland;

* Correspondence: marcin.kudzin@lit.lukasiewicz.gov.pl; Tel.: +48-42-6163121

Table S1. Chemical composition of linen^{a-i}

Cellulose ^c	Hemicellulose ^d	Pectin ^e	Lignin ^f	Wax ^g	Lit.
					
71.0	18.6-20.6		2.2		[S1]
79.0	11.0	5-12.0	3.0	1.5	[S2]
70-81.0	20.6-16.7		3.0-10.0		[S3,S4]
62-72.0	18.6-20.6		2.0-5.0		[S5]
64.1-75.0	10.4-20.6		2.0-5.0		[S6]
64.1-71.9	18.6-20.6		2.0-2.2	1.7	[S7]
40-50.0	20-40.0		20-35.0		[S8]
83.0	11.0		2.0		[S9,S10]
68.2-68.9; 75.0-75.5; 72.2-73.5 ^h	29.4-32.0; 19.6-23.9; 16.4-20.4 ^h	4.2-4.6; 4.4-5.4; 3.6-4.7 ^h	4.2-5.3; 4.2-6.7; 4.3-6.1 ^h	0.9-1.2; 0.7-1.3; 1.0-1.7 ^h	[S11]

^{a-h}/Legend and Supplement information:

^b/Structural features: R=MeO, HO; R¹=alkyl; n= PD; k=1-7; m=1-3; l=7.

^c/Cellulose - a carbohydrate polymer generated from repeating β -D-glucopyranose molecules covalently linked through acetal functions between the equatorial OH group of C⁴ and the C¹ carbon atom (β -1,4-glucan) [S12].

^d/ Hemicelluloses (xyloglucans, xylans, mannans and glucomannans, and β -(1 \rightarrow 3,1 \rightarrow 4)-glucans) polysaccharides (hexoses and pentoses) with β -(1 \rightarrow 4)-linked backbones with an equatorial configuration [S13].

^e/Pectins are a family of complex polysaccharides that contain in majority 1,4-linked α -D-galactosyluronic acid units with varying degrees of carboxyl groups methylesterified, and hydroxyl groups acetylated [S14,S15].

^f/ Lignin, a natural complex polymer containing the most abundant aromatic structures in nature with no defined structure, however it is made up of three primary alcoholic monomers (p-coumaryl (X¹=X²=H), coniferyl (X¹=H, X²=OMe) and sinapyl (X¹=X²=OMe) alcohol) combined by various type of ether linkages [S16].

^g/ Cotton/linen fiber wax is a complex lipid material that forms the major component of an outer hydrophobic barrier on the cotton fiber surface.

^h/Linen decorticated, degummed or cottonized, respectively.

ⁱ/Data: the results were rounded to the first decimal place.

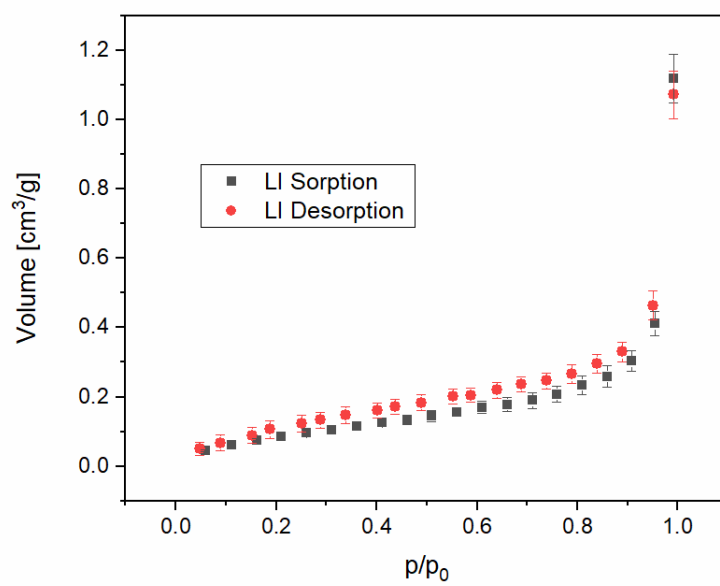
Table S2. Chosen mechanical properties of linen and cotton

Fiber	Mechanical properties of Linen (LI) and cotton (COT)								Lit.
	Dens. (g)	ELB	TS(STS)	EM	St/YM	SSt/ SYM	L/W	USt	
LI	1.5		345-1830 (230-1220)		18-53	18-53	5-900		[S17]
	1.4	1.2-3.0	343-1035	28	50-70		33/19	500-900	[S18]
	1.2-1.5	1.0-4.0	343-2000	24-103					[S7]
	1.4-1.5		800-1500 /(550-1030)		55-75				[S19]
	0.6-1.5	1.2-10	88-1600	24-80					[S6]
COT	1.5-1.6		287-800 (190-530)		5.5-13	3.7- 8.4	10-60		[S17]
		7.0-8.0	287-587	5.0-13.0			25/20		[S18]
	1.5-1.6	2.0-10.0	287-800	5.5-13.0					[S7]
	1.5-1.6	3.0-10.0	45-1000	5.5-12.6					

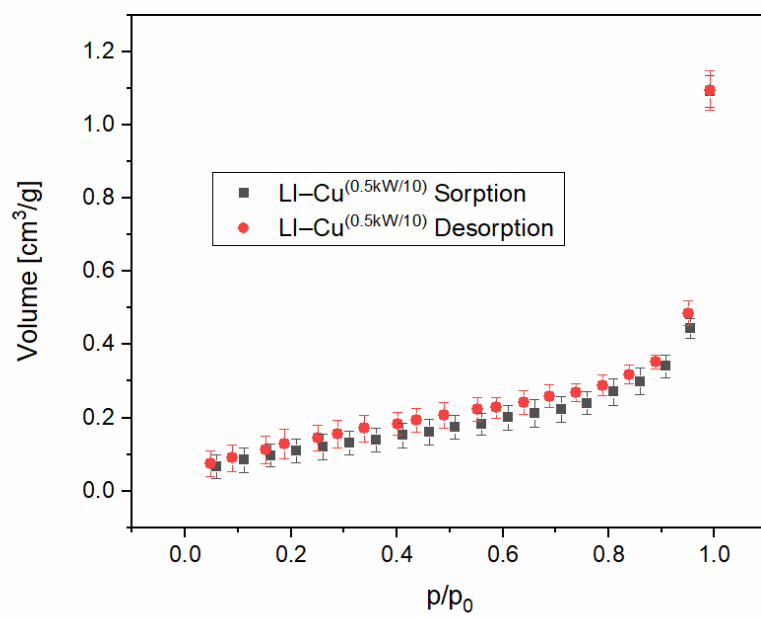
Dens. – density (g/cm³); ELB - Elongation at Break (%); EM - elastic modulus (young's modulus)(GPa); USt - Ult. Stress (MPa); Sizes: L- Length (mm); W- Width (mm); St - stiffness (GPa); SS - Specific stiffness (GPa/gcm⁻³); TS - tensile strength (MPa); STS - Specific tensile strength (MPa/gcm⁻³); SYM - Specific Young's modulus

Table S3. Results of copper content analysis and surface property testing, including specific surface area and total pore volume. The research was performed in three distinct and separate experimental trials. A subset of key results from these trials was then selected and subjected to thorough analysis and presentation.

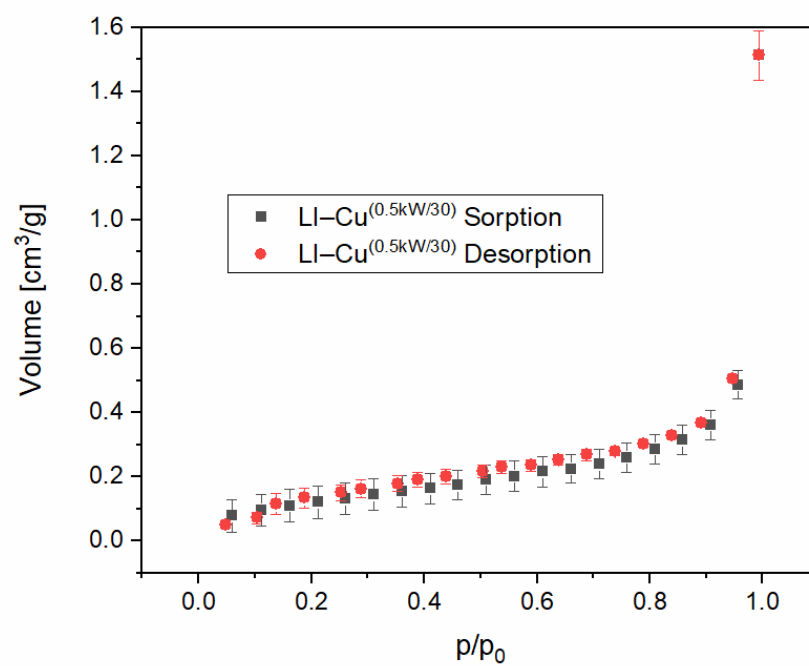
Sample name	Cu concentration			Total Pore Volume			Specific Surface Area		
	[g/kg]	Mean [g/kg] ± SD	p-value	[10 ⁻³ cm ³ /g]	Mean [cm ³ /g] ± SD	p-value	[m ² /g]	Mean [m ² /g] ± SD	p-value
LI	0			1.980			0.320		
	0	0	-	1.950	1.974 ± 0.021	-	0.325	0.3245 ± 0.012	-
	0			1.992			0.328		
LI-Cu ^(0.5kW/10°)	5.42			1.610			0.348		
	5.90	5.90 ± 0.48	p < 0.05	1.620	1.615 ± 0.005	p < 0.05	0.350	0.3495 ± 0.010	p < 0.05
	6.38			1.615			0.351		
LI-Cu ^(0.5kW/30°)	15.97			2.450			0.415		
	15.51	15.74 ± 0.23	p < 0.01	2.470	2.460 ± 0.008	p < 0.01	0.420	0.4185 ± 0.015	p < 0.01
	15.74			2.460			0.420		
LI-Cu ^(1kW/10°)	10.95			2.040			0.390		
	11.35	11.20 ± 0.28	p < 0.05	2.050	2.048 ± 0.007	p < 0.05	0.395	0.3927 ± 0.014	p < 0.05
	11.30			2.055			0.393		
LI-Cu ^(1kW/30°)	29.30			1.770			0.430		
	29.95	29.72 ± 0.47	p < 0.01	1.780	1.778 ± 0.006	p < 0.01	0.435	0.4343 ± 0.016	p < 0.01
	29.91			1.785			0.438		



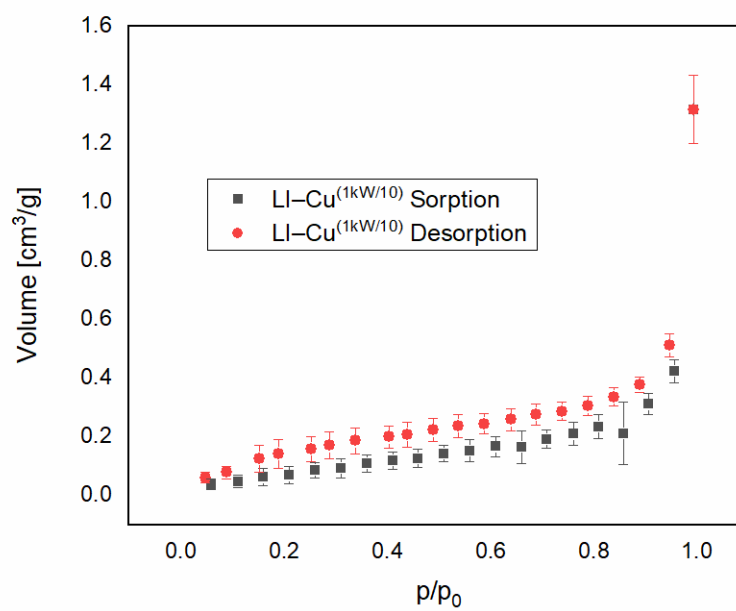
A



b



c



d

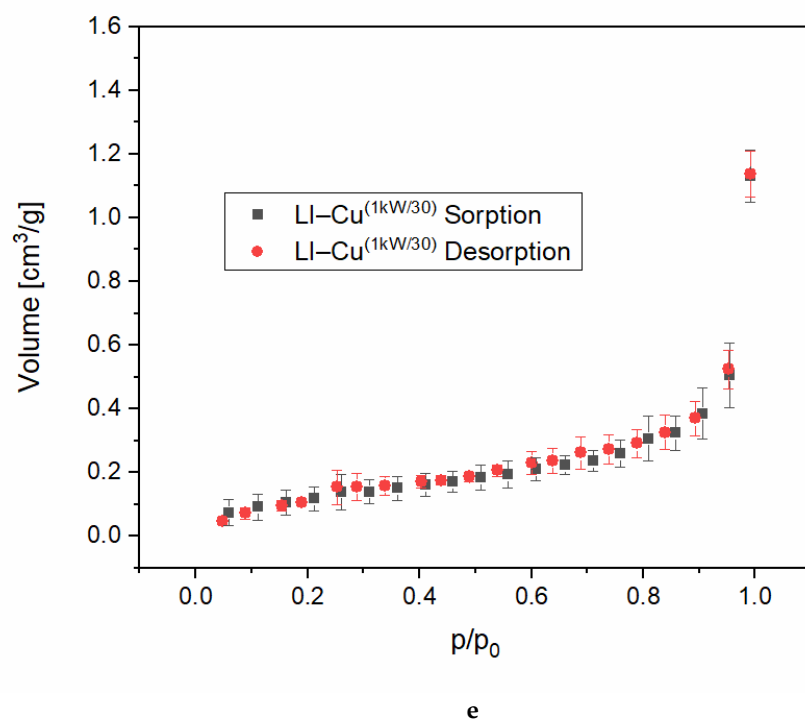
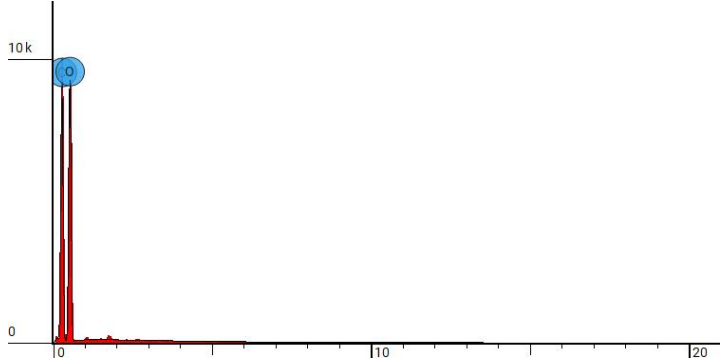


Figure S1. N₂ adsorption-desorption isotherms for samples: (a) LI; (b) LI-Cu^(0.5kW/10); (c) LI-Cu^(0.5kW/30); (d) LI-Cu^(1kW/10); (e) LI-Cu^(1kW/30). The research was performed in three distinct and separate experimental trials. A subset of key results from these trials was then selected and subjected to thorough analysis and presentation.

Sample name	EDS	Element Symbol	Atomic Conc.	Weight Conc.
LI		C	Carbon	45.271
		O	Oxygen	54.729
LI-Cu(0.09)		C	43.344	29.000
		O	48.915	43.600

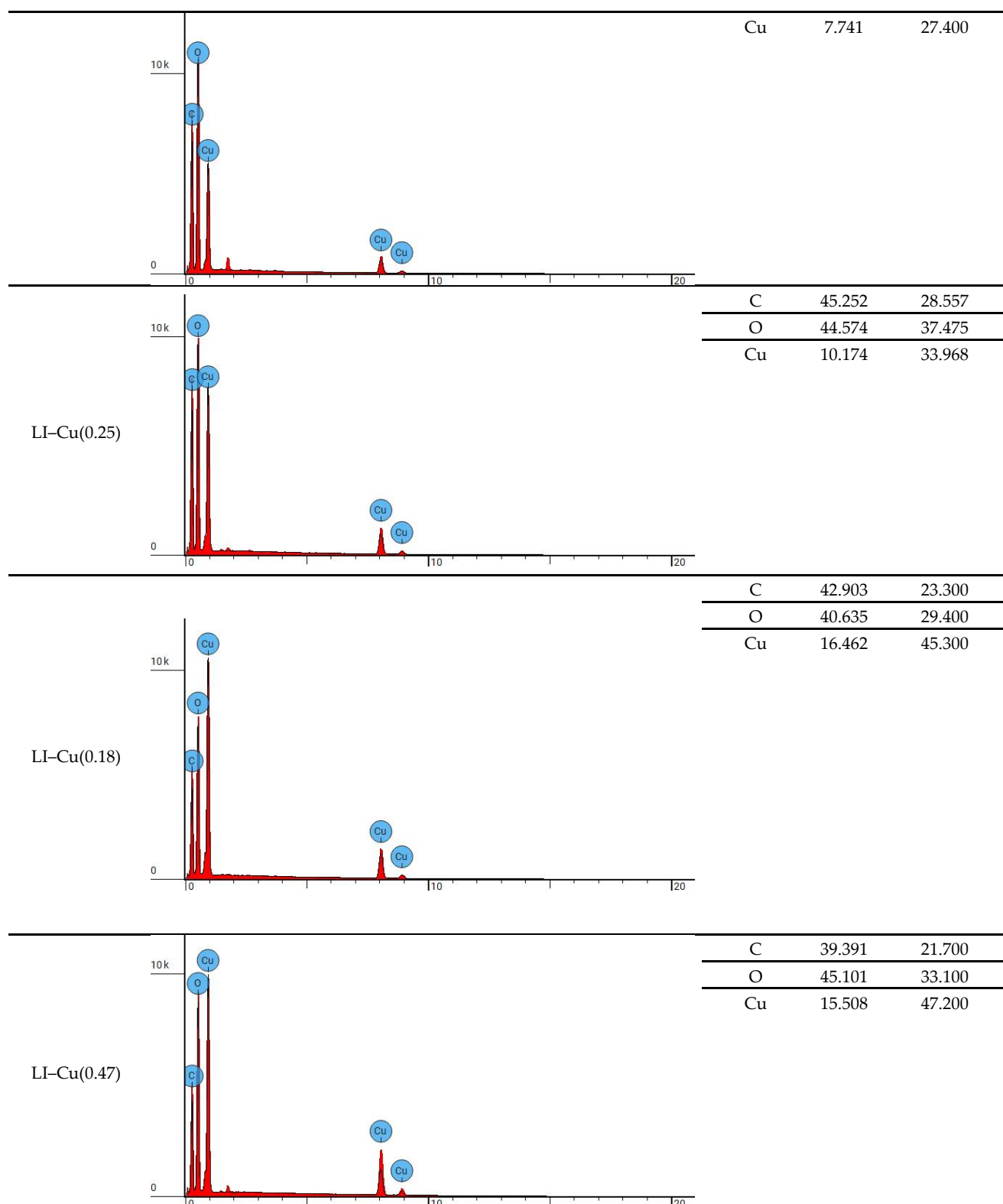


Figure S2. Spot analysis diagrams obtained from energy-dispersive X-ray spectroscopy (EDS) of LI-Cu samples, along with the experimental data from EDS analysis. The research was performed in three distinct and separate experimental trials. A subset of key results from these trials was then selected and subjected to thorough analysis and presentation.

Table S4. Comparison of microbicidal activity of LI-Cu with other polymer-metal materials and microbicidal agents.

Sample ^a	Deposition ^b		Zone inhibition diameter (ZID) ^c [mm]				LIT
			Bacteria and Fungi ^d				
			Bacteria		Fungi		
	mg/g	M/MLL	<i>Ec</i>	<i>Sa</i>	<i>An</i>	<i>Cg</i>	
LI	-	-	0	0	0	0	This work
LI-Cu(0.01)	0.6	0.01	0	0	0	0	This work
LI-Cu(0.04)	2.5	0.04	1	0	0	0	This work
LI-Cu(0.09)	5.7	0.09	1	1	1	1	This work
LI-Cu(0.18)	11.4	0.18	1	1	1	2	This work
LI-Cu(0.25)	15.9	0.25	1	2	1	2	This work
LI-Cu(0.47)	29.8	0.47	2	2	1	3	This work
CNW-Cu ⁰ (0.2)	12.7	0.2	2	1	1	2	[S20]
CNW-Cu ⁰ (0.4)	25.4	0.4	3	2	3	2	[S20]
PLA-Cu(0.2)	9.9	0.2	2	1		1	[S21]
PLA-Cu(0.4)	27.9	0.4	2	1		3	[S21]
WO-Cu ⁰ (0.1)	3.5	0.1	1	1		1	[S22]
WO-Cu ⁰ (0.4)	24.3	0.4	3	2		1	[S22]
PET-Cu(0.1)	6.7	0.1	1	1		3	[S23]
PET-Cu(0.2)	14.4	0.2	2	1		3	[S23]
COT-Zn(0.1)	9	0.1	1	0			[S24]
COT-Zn(0.7)	42	0.6	1	1			[S24]
CuCl ₂		0.05	15	14		63.5	[S25]
AgNO ₃		0.05	16	15			[S25]
AuNPS ^f	10 µg/mL		12.7	8.6			[S26]
AuNPS ^g	10 µL		14.2				[S27]
CuNPS ^h		0.05	17	16			[S25]
Ampicillin	10 µg/mL		16.5	16.3			[S26]
Ciprofloxacin	10 µL		14.3				[S27]
Gentamycin	0.01	0.02	19	13			[S25]

^{a/} CNW-Cu – Cotton Non-Woven–Copper materials; PLA-Cu – Polylactic Acid–Copper materials; WO-Cu – Wool-Copper materials; PET-Cu; CuCl₂ – copper chloride aqueous solution; AgNO₃ – silver nitrate aqueous solution; Nanoparticles: AuNPS – gold nanoparticles; CuNPS – copper nanoparticles; Antibiotics (control substances): Ampicillin; Ciprofloxacin and Gentamycin.

^{b/} Deposited on discs as originally assigned (µg/mL, mg/mL, mmol/kg, mmol/L; mg/disc; milimolal in the solution or solid sample).

^{c/} Zone inhibition diameter (ZID), rounded to whole numbers (mm); determined according to PN-EN ISO 20,645:2006 or PN-EN 14119:2005 standards. Results are presented as mean results from three repeats.

^{d/} Bacteria and Fungi: *An* – *Aspergillus niger*; *Cg* – *Chaetomium globosum*; *Ec* – *Escherichia coli*; *Sa* – *Staphylococcus aureus*.

^{e/} Concentration of inoculum: *A. niger*: 1.9×10^6 CFU/ml, *C. globosum*: 2.5×10^6 CFU/ml; *E. coli* – 1.3×10^8 CFU/ml, *S. aureus* – 1.9×10^8 CFU/ml.

^{f/} Synthesized by reduction of AuCl₃ by *Jatropha integerrima* Jacq. flower extract.

^{g/} Synthesized by reduction of H₂O₂ by panchagavya (PG)

^{h/} Synthesized by reduction of CuCl₂ by ascorbic acid;

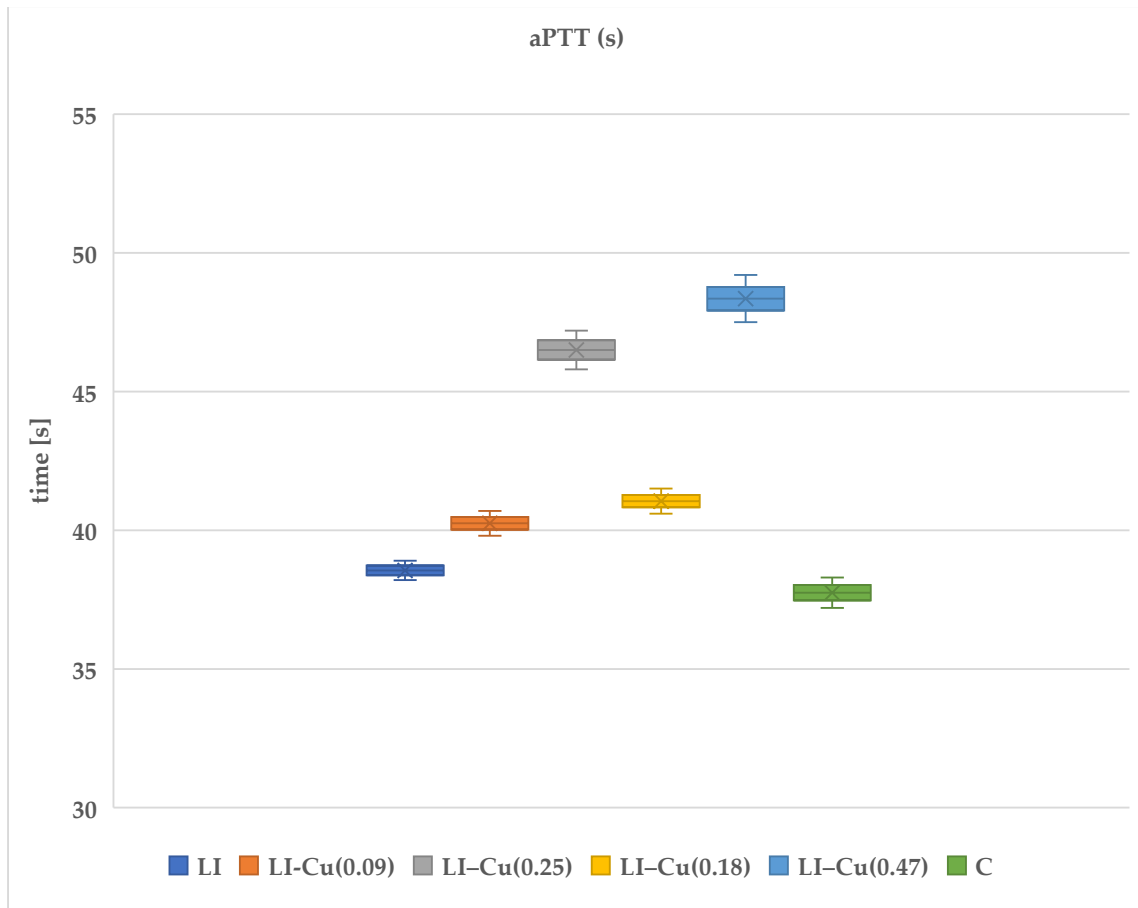


Figure S3. The impact of the copper-coated linen materials on aPTT was evaluated for various samples: LI; LI-Cu(0.09); LI-Cu(0.25); LI-Cu(0.18); LI-Cu(0.47); and C, the control sample. Results are displayed with the mean (×), range (bars), median (horizontal line), and interquartile range (box). The study involved three separate experimental runs, from which a selection of significant findings was chosen for detailed analysis and presentation.

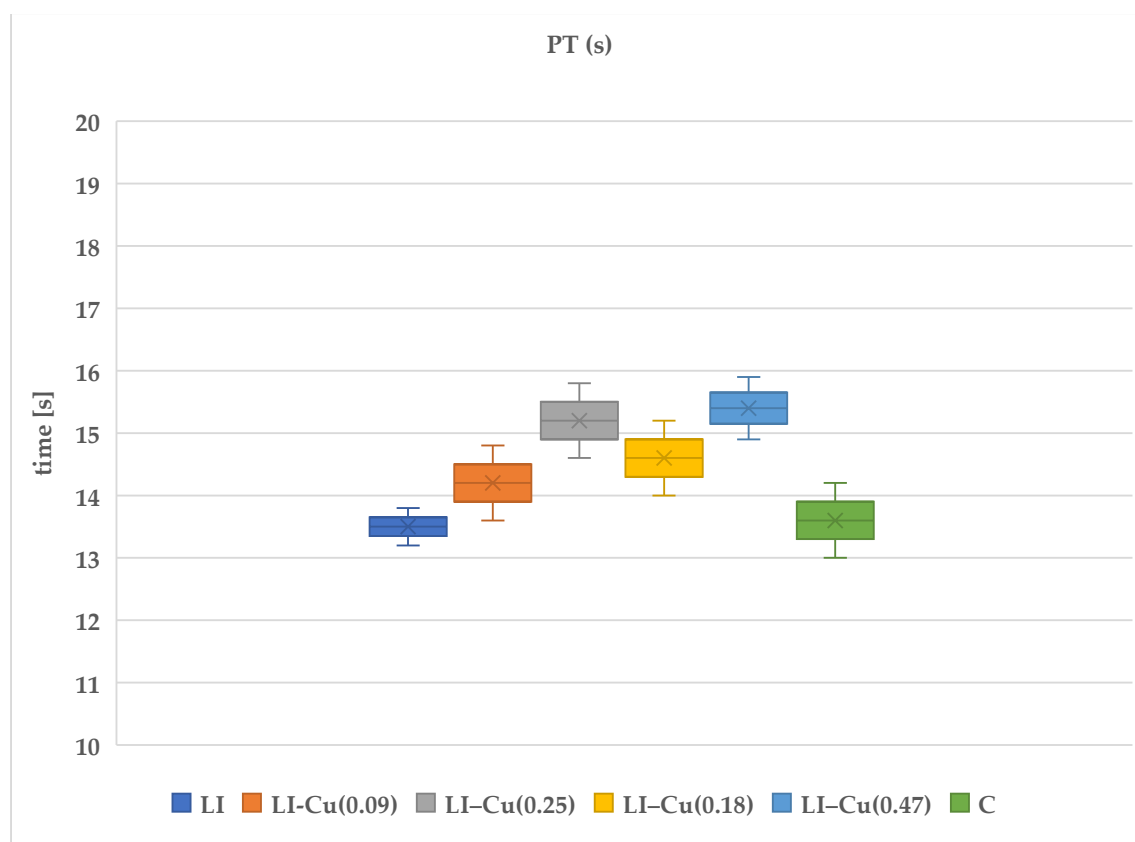


Figure S4. The impact of the copper-coated linen materials on PT was evaluated for various samples: LI; LI-Cu(0.09); LI-Cu(0.25); LI-Cu(0.18); LI-Cu(0.47); and C, the control sample. Results are displayed with the mean (\times), range (bars), median (horizontal line), and interquartile range (box). The study involved three separate experimental runs, from which a selection of significant findings was chosen for detailed analysis and presentation.

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