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# *Pinus Nigra* Essential Oil and Its Main Active Components as Sustainable Compounds for Mitigation of Carbon Steel Corrosion

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The use of compounds for corrosion protection such as chromates and some synthetic organic substances is prohibited or restricted due to their hazardous and carcinogenic nature. Recently, research has been focused on green corrosion inhibitors, whose name is mostly associated with plant essential oils and extracts that are environmentally friendly, non-toxic, inexpensive, not harmful to human health, and with high corrosion inhibition efficiency. Many plant oils and extracts have been used as effective corrosion inhibitors for steel in hydrochloric acid (HCl) solution, and they are a rich source of bioactive components.

The inhibitory properties of *Pinus nigra* needle essential oil (PN), as well as its active ingredients, were analyzed on a carbon steel sample in a 1M HCl solution. The dominant components of this essential oil are α-pinene (66,529 %), germacrene D (14,054 %), (E)-caryophyllene (5,671 %), and β-pinene (2,105 %). The effectiveness of the inhibition was investigated using electrochemical methods such as electrochemical impedance spectroscopy and potentiodynamic polarization measurements. It has been shown that the effectiveness of all inhibitors increases with time. The most abundant substance in the essential oil, α-pinene, showed a lower corrosion inhibition efficiency compared to β-caryophyllene at the same concentration of 80 ppm. Based on the recorded polarization curves, it was concluded that black pine essential oil, as well as its components, act as mixed-type corrosion inhibitors, reducing the rate of both anodic and cathodic reactions. The inhibition capacity of PN could be ascribed to the adsorption of its organic constituents on the surface of carbon steel.

**Keywords:** corrosion, carbon steel, green inhibitors, EIS, polarization measurements.

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