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Economic and Environmental Impact of Traditional Rust Preventives as Compared to Novel Bio-based Temporary Coatings

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Rust preventatives

- Agents used for preservation of metals during shipment, storage, or between processes.
- Forming a temporary protective coating on metal surface, keeping it free from rust.
- Traditionally used oil- and solvent-based products offering sufficient corrosion protection but containing hazardous ingredients; not readily biodegradable.
- Industry turning to „green” bio-based products.

Guiding thought

RUST


RUST


Selection

- A proper selection of rust preventative depends on:
  - storage and/or transport conditions,
  - protection period,
  - economic impact.
- In addition the product should:
  - provide no interference with the function of the metal part or surface,
  - be safe and friendly to the environment and the workers using it,
  - be easy to remove from surface after usage.

Goal of research

- The goal of this research is to show that bio-based products may inhibit corrosion as well as their traditional oil- and -solvent based counterparts, without negative environmental considerations.
- The corrosion parameters as well as economic properties of five different rust preventatives used for temporary corrosion protection was studied.

Study

- 1 bio-based which combines film-forming additives with vapor phase corrosion inhibitors (VpCI) and
- 4 conventional solvent- and oil- based products, which leave a temporary waxy protective film on metal surface.

Label	Manufacturer	Type	Density [g/cm³]	Flashpoint [°C]	General description
INH1	Cortec Corp. BioCorr	water/bio	1.00-1.01	not applicable	waterbased, biobased and biodegradable, VOC-free
INH2	Fuchs	solvent	0.91	200	concentrate dilutable with white sprit (70:30)
INH3	Castrol	solvent	0.8	> 38	rust inhibitor that leaves an ultra-thin greasy film
INH4	Houghton	solvent	0.799	48	rust inhibitor that leaves waxy film
INH5	Fuchs	mineral base oils / solvent	0.79	40	mixture based on mineral base oils and corrosion preventative agents in volatile hydrocarbons

Economical study

- The cost analysis is performed according to:
  - market price of the product,
  - disposal cost, based on European Waste Catalogue number,
  - transport cost, based on 100 liters of product,
  - warehousing cost.

Label	Cost [EUR/l]	Disposal cost [EUR/l]	Transport cost [EUR/l]	Warehousing cost [EUR/l]	Total cost [EUR/l]	Protection time /indoor storage [months]
INH1	2.52	0.27	0.45	0.03	3.27	24
INH2	4.44	0.573	0.45	0.03	5.49	12-36
INH3	4.75	0.427	0.56	0.04	5.78	9
INH4	5.84	0.573	0.56	0.04	7.01	12
INH5	2.99	0.427	0.56	0.04	4.02	6-12

INH1 > INH5 > INH2 > INH3 > INH4

Lowest to Highest

Experimental study

- Resistance to humidity environment; accelerated corrosion testing using a humidity chamber, in an effort to simulate conditions during transport and shipping.
- Corrosion inhibition efficiency; electrochemical testing by means of polarization techniques on Potenciostat 237A / SoftCorr III, after 1 and 120 hours in fresh water.
- Cleanability; easy removal ensures protected metal components can be quickly used, minimizing downtime and maximizing production output.

Rust preventative application

- The carbon steel samples, dimension 60x100x1 mm, were polished with sandpaper (240 grit), immersed in methanol for 5 minutes, dipped in rust preventatives for 30 minutes, and then allowed to air dry for 24 hours.
- Before testing, thickness measurement was performed using gravimetric method.

Sample	Label	Density $[g/m^3]$	Weight of applied rust preventative [g]	Surface $[m^2]$	Film thickness [µm]	Average film thickness [µm]
1	INH1	1000	0.0226	0.012	1.8833	1.3833
11			0.0106	0.012	0.8833	
2	INH2	910	0.1068	0.012	9.7802	10.2747
22			0.1176	0.012	10.7692	
3	INH3	800	0.0116	0.012	1.2083	1.2135
33			0.0117	0.012	1.2187	
4	INH4	799	0.0188	0.012	1.9608	2.0598
44			0.0207	0.012	2.1589	
5	INH5	790	0.0087	0.012	0.9177	0.8808
55			0.0080	0.012	0.8439	

10x

Humidity chamber testing

- ISO 6270-2 (RH 100% and 40 ± 3 °C)
- 600 hours in C&W Humidity cabinet, model AB5
- Atmosphere of constant condensing humidity, representing warehouse and/or transport environment.
- Pass/fail evaluation in accordance to ASTM D-1748 (three spots, smaller than 1 mm, allowed)

Humidity chamber testing

PASS, two corrosion spots observed smaller than 1 mm

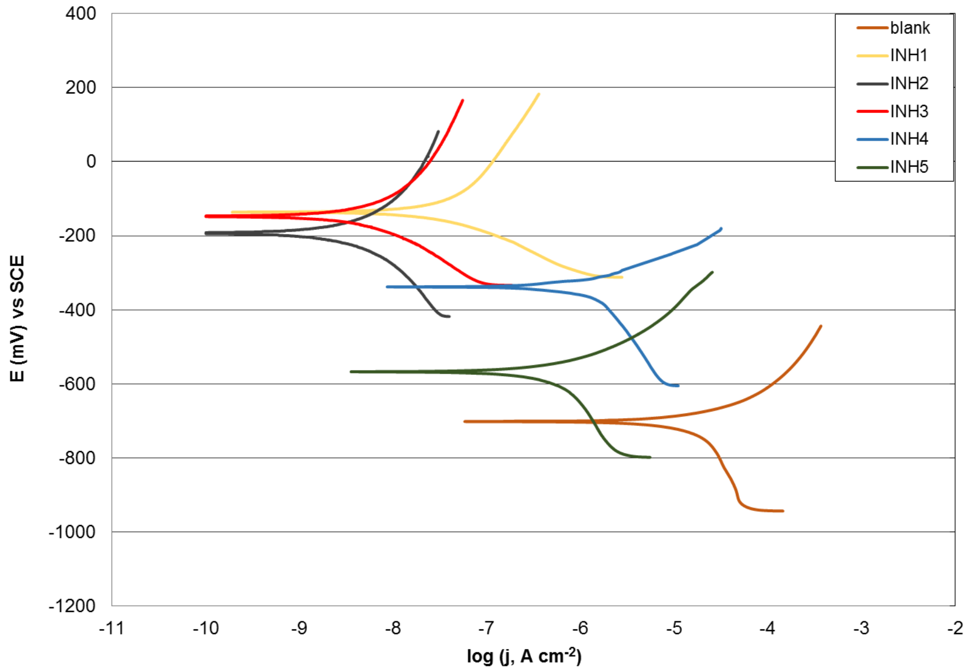
FAIL, first signs of localized corrosion occur at 100 hours, larger than 1 mm

FAIL, four corrosion spots observed

PASS, one corrosion spot observed smaller than 1 mm

PASS, one corrosion spot observed smaller than 1 mm

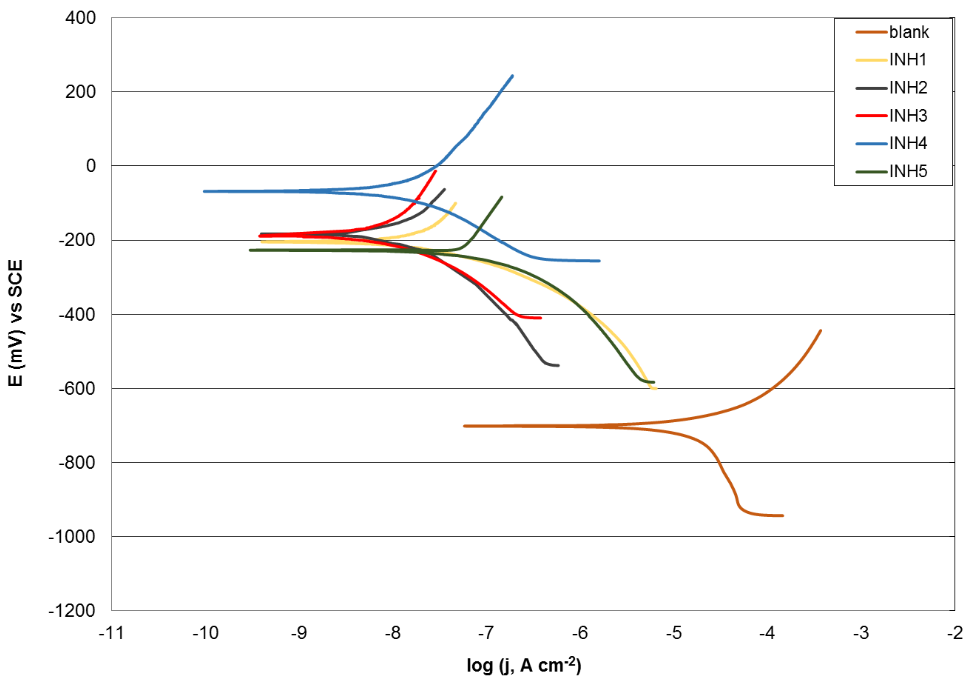
Polarization measurements after 1 hour in fresh water



- compared to unprotected carbon steel (blank curve)
- corrosion current density decreased with introduction of rust preventatives
- potential shift to noble values

Sample	E_{corr} [mV]	j_{corr} [μA/cm²]	β_a [V/dek]	β_c [V/dek]	v_{corr} [mm/god]
blank	-686	25.87	117.1×10^{-3}	768×10^{-3}	170.8×10^{-3}
INH1	-136	55.18×10^{-3}	393.4×10^{-3}	136.9×10^{-3}	364.2×10^{-6}
INH2	-194	19.93×10^{-3}	942.1×10^{-3}	708.4×10^{-3}	131.6×10^{-6}
INH3	-149	10.16×10^{-3}	341.1×10^{-3}	203.5×10^{-3}	67.06×10^{-6}
INH4	-338	1.709×10^{-3}	123.4×10^{-3}	413.6×10^{-3}	11.28×10^{-3}
INH5	-567	841.9×10^{-3}	125.5×10^{-3}	553.6×10^{-3}	5.557×10^{-3}

Polarization measurements after 120 hours in fresh water

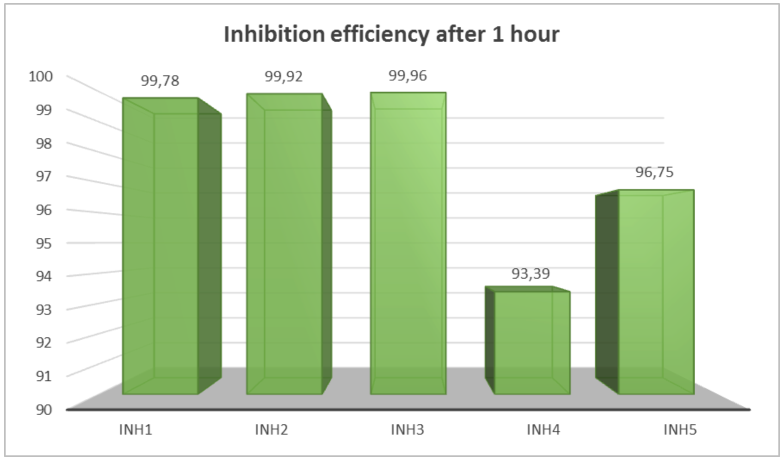


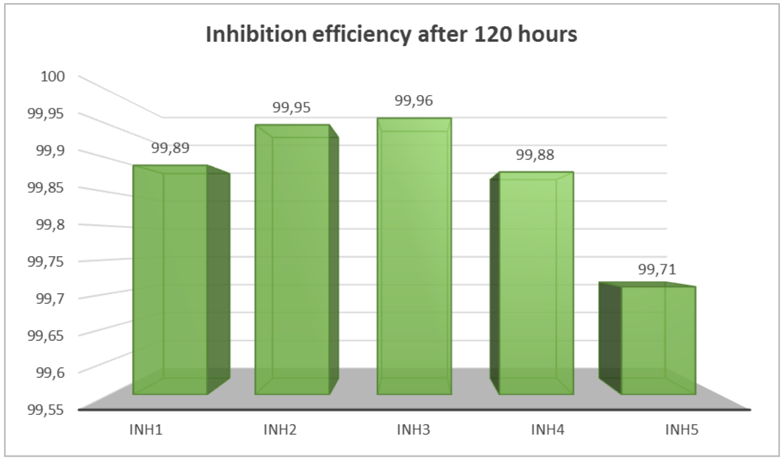
- all tested rust preventatives showed improved inhibition efficiency,
- it can be attributed to a longer period for film forming on the metal surface.

Sample	E_{corr} [mV]	j_{corr} [μA/cm^2]	β_a [V/dek]	β_c [V/dek]	v_{corr} [mm/god]
blank	-686	25.87	117.1×10^{-3}	768	170.8×10^{-3}
INH1	-205	27.99×10^{-3}	445.8×10^{-3}	82.37×10^{-3}	184.7×10^{-6}
INH2	-182	13.22×10^{-3}	128.3×10^{-3}	214.4×10^{-3}	87.25×10^{-6}
INH3	-193	9.957×10^{-3}	398.5×10^{-3}	82.40×10^{-3}	65.72×10^{-6}
INH4	-67	31.18×10^{-3}	473.0×10^{-3}	194.5×10^{-3}	205.8×10^{-6}
INH5	-226	76.10×10^{-3}	174.3×10^{-3}	110.3×10^{-3}	502.3×10^{-6}

Inhibition efficiency

$$\eta_i = \frac{(v_{corr})_{ni} - (v_{corr})_i}{(v_{corr})_{ni}} \cdot 100\%$$





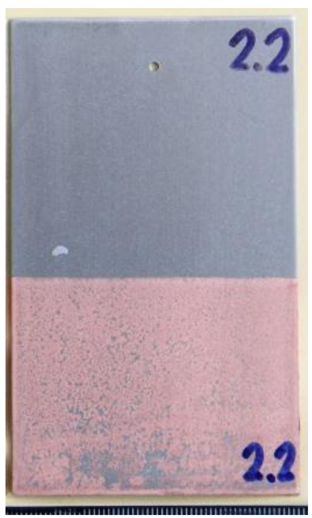
INH3 > INH2 > INH1 > INH5 > INH4

INH3 > INH2 > INH1 > INH4 > INH5

Cleanability evaluation

- By dipping into a copper sulphate plating solution
- Results:
  - INH1 and INH4 showed effective cleanability
  - INH2 showed moderate cleanability
  - INH3 and INH5 showed insufficient cleanability.

PASS, effective cleanability



FAIL, 5% of surface still covered with RP

FAIL, 30% of surface still covered with RP

PASS, effective cleanability

FAIL, 70% of surface still covered with RP

CONCLUSION

The results of this study are summarized as follows:

- Three of the five rust preventatives passed 600 hours of humidity testing; including bio-based product, along with two of the solvent based products.
- Higher thickness of rust preventative didn’t provide better corrosion protection. Furthermore, increased thickness had a negative influence on cleanability.
- Bio-based rust preventatives offer optimal corrosion protection, with no increase in protection cost, compared to petroleum-based and hazardous rust preventatives.

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