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# *Release rates of alloy constituents from stainless steel*

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**Aim:**
**To present a selection of results related to possible environmental effects of stainless steel**

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## *Experimental*

**Synthetic Body Fluids**

**Stainless steel massive products**

**Ferritic**
**Austenitic**
**Duplex**

**Stainless steel powder particles**

**Austenitic**

**Metal release rates**

**Natural and artificial rain**

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## *Why is it important to provide metal release data of alloy constituents from stainless steels?*

- **Stainless steels are used in a wide variety of areas and applications.**
- **Scarce or no data available on metal release rates of alloy constituents.**
- **Lack of understanding of differences between alloys and the pure metals.**
- **Knowledge gaps concerning potential environmental or health effects of alloy constituents released from stainless steel.**

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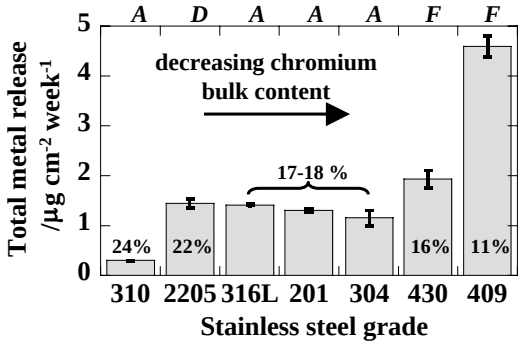
## *How does alloying influence the metal release rates?*




*One-week exposure in artificial lysosomal fluid (ALF).*

**Metal release rates decrease with increasing chromium bulk content: 409 >> 430 > 2205, 316L, 201, 304 > 310.**

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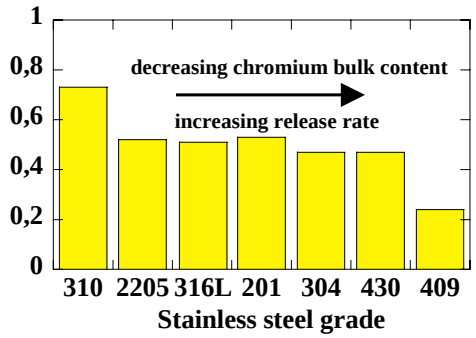
## *How does alloying influence the metal release rates?*

*Cr/(Cr+Fe) in passive film, as obtained by XPS*




*One-week exposure in ALF.*

**Total weekly metal release rates are related to the degree of alloying. Other factors such as surface finish, surface film thickness and composition, steel microstructure, and presence of defects also influence the release rate.**

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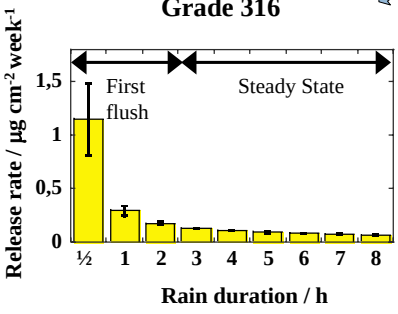
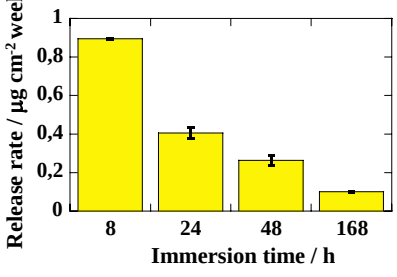
## *Is the metal release process of alloy constituents time-dependent?*

**Chromium**

**Artificial Rain Grade 316**




**ALF Grade 316L**




**Stainless steel exhibits a decrease in metal release rate with time of all alloy constituents in all fluids investigated.**

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## *How much is one μg cm$^{-2}$ week$^{-1}$?*


**One μg cm$^{-2}$ week$^{-1}$ corresponds to one nanometer of stainless steel that is released every week, or one micrometer released every 20 years !**

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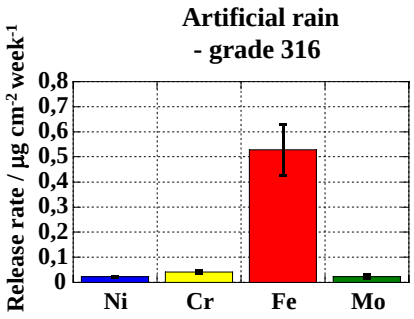
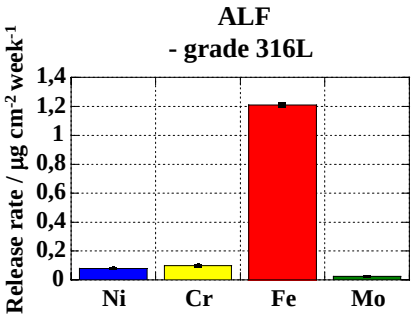
## *Is the release rate the same for all alloy constituents?*




**Iron is preferentially released compared to nickel, chromium and molybdenum from all grades, surface finishes and fluids investigated.**

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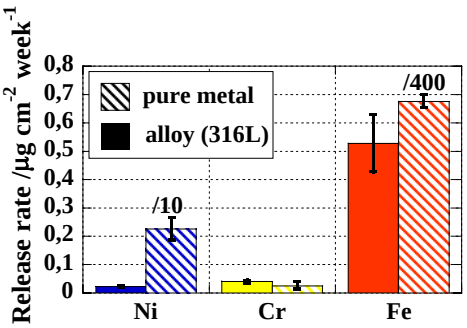
## *Are release rates of alloy constituents from stainless steels equal to release rates from the pure metals?*




**The presence of a chromium rich passive film on stainless steel reduces the release rates of iron and nickel compared to the pure metals. Similar release rates of chromium from stainless steels and the pure metal.**

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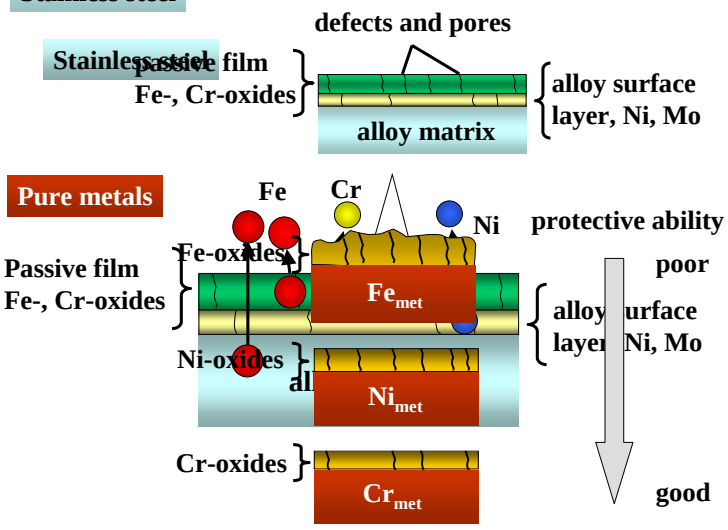
## *Schematics of release rate mechanisms*



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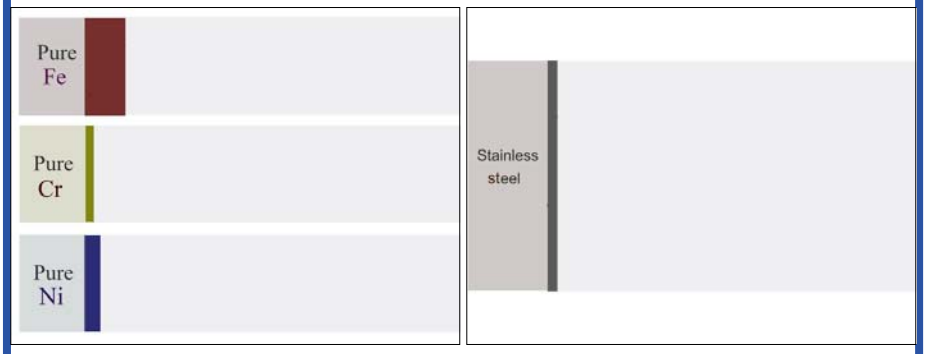
## *Metal release rates of alloy constituents from stainless steel compared to metal release rates from the pure metals*

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## *Metal concentrations in runoff rain water compared to WHO recommendations*

**Metal concentrations in runoff rain water (Stockholm):**

- **≤ 1.2 µg Cr $L^{-1}$**
- **≤ 0.7 µg Ni $L^{-1}$**
- **≤ 15 µg Fe $L^{-1}$**

**WHO recommendations for drinking water:**

- **< 50 µg Cr $L^{-1}$**
- **< 20 µg Ni $L^{-1}$**
- **< 300 µg Fe $L^{-1}$**

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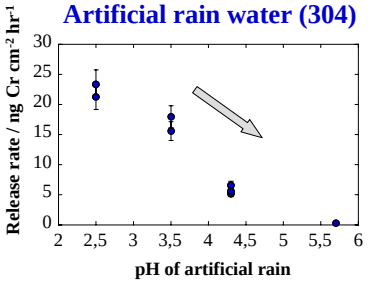
## *Summary of release rates measured in different solutions*

| *Total release rate* | *μg cm$^{-2}$ week$^{-1}$* |
|---|---|
| Rain (pH 4.3) | 0.61 |
| ALF (pH 4.5) | 1.3 |
| Gamble's solution (pH 7.4) | 0.075 |

**Release rates increase with acidity of solution.**

**Artificial rain water (304)**

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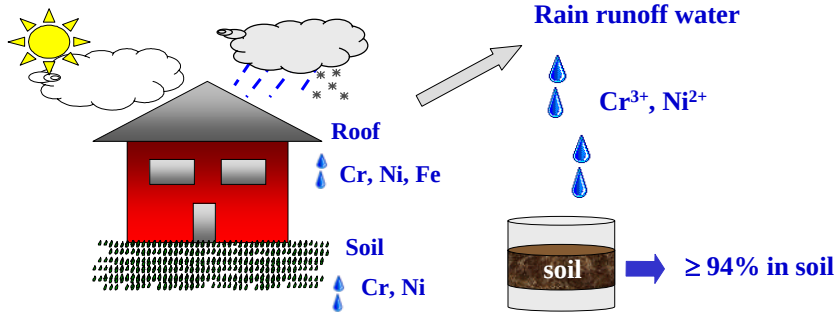
## *What happens with chromium and nickel in rain runoff water on contact with soil?*




**Interacting media, such as soil, possess a strong ability to retain the metals.**

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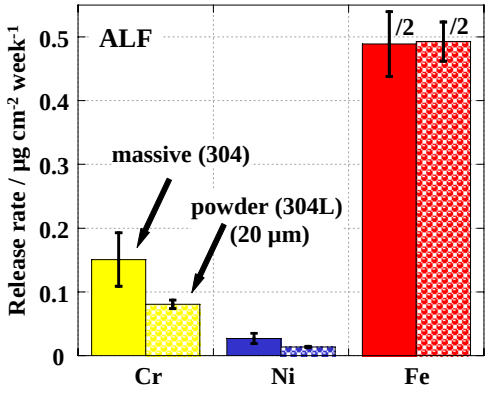
## *Do small stainless steel powder particles exhibit different release rates than massive flat surfaces?*




**Our investigations so far do not suggest any significant differences**

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## *Concluding remarks*

- **Scarce or no data available on metal release rates of alloy constituents.**

***Metal release rate data are now available for a variety of solutions and stainless steel grades.***

- **Lack of understanding of differences between alloys and the pure metals.**

***The release rates of iron and nickel from stainless steel are significantly lower than from the pure metals. Release rates of chromium from stainless steel and the pure metal are similar.***

- **Knowledge gaps concerning potential environmental or health effects of released alloy constituents from stainless steel.**

***Total release rates from stainless steels are very low and generally decrease with increased chromium content in the steel.***

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## *Publications and on-going work*

***Experimental development***

***Publications in peer-reviewed literature***
***Reports***
***Conference proceedings***
***Academic theses***

***To be continued…***

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## *Acknowledgement*

EUROFER
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International Stainless Steel Forum
ISSF