Since I receive so many questions on this blog pertaining to products made from stainless steel, I thought I'd give you some background about what stainless steel is and how it leaches into various foods and beverages.

Steel is used to make a wide variety of industrial, construction, and consumer products. The largest use by far for consumer products is to make auto bodies and "tin cans" (actually made of steel with a very thin protective coating of tin), although it is also used to make appliances, cutlery, flatware, razor blades, cookware, water bottles, and many other items.

**What Steel is Made From**

Steel, by definition, is made primarily from iron. Iron is a naturally-occurring metallic element. It is rarely found on the surface of the earth because it oxidizes readily in the presence of oxygen and moisture, and disintegrates into rust. Iron used in products, such as cast iron, is made from the iron ore hematite, from which oxygen has been removed by heating to high temperatures. So when a product is made primarily from iron, it will naturally rust.

Pure single crystals of iron are very soft, so other metals are added to strengthen it. These are called "alloys". Alloying iron with small amounts of other metals and carbon produces steel, which can be 1,000 times harder than pure iron.

There are two basic types of steel: carbon steel and stainless steel.

The type of steel used to make auto bodies, cans, cutlery, and woks is plain **carbon steel**, produced by the Basic Oxygen Furnace process. You can easily tell that it is...
carbon steel because it turns black over time and easily rusts when exposed to air and moisture. Made simply of iron with 0.1 to 1.2 percent carbon and even less manganese, carbon steel can be recycled and often contains a minimum of 25 percent recycled content whether it is so labeled or not. The Electric Arc Furnace process, which is used to produce steel shapes such as railroad ties and bridge spans, uses virtually 100 percent recycled steel.

Most consumer products made from steel, however, such as cookware and bakeware, cooking utensils, and flatware, are made from **stainless steel**, which has a special ability to resist stains and corrosion (so it doesn't rust or turn black). The average stainless steel object is made of about 60% recycled material of which about 40% originates from products consumers have recycled and 60% comes from manufacturing processes. ([The Recycling of Stainless Steel](https://www.iso.org/obp/ui/#iso:std:iso:17498-3:ed-1:v1:en))

In metallurgy, stainless steel is defined as a steel alloy with a minimum of 11% chromium content by mass. The addition of chromium prevents the corrosion that causes rust, and also prevents stains, thus the name "stainless steel."

The chromium--and this is an important point with regards to metal toxicity--forms a layer of chromium oxide over the steel when exposed to oxygen. This layer is impervious to water and air, protecting the metal beneath. *This layer quickly reforms when the surface is scratched, so when a food or beverage or your body comes in contact with stainless steel, what it is actually contacting is chromium.*

There are more than 150 grades of stainless steel, of which fifteen are most common. In addition to chromium, nickel and manganese are added to some alloys.

More than 70% of stainless steel production is of the 300 series, which produces a particular crystalline structure called "austenitic." These contain a maximum of 0.15% carbon, a minimum of 16% chromium and sufficient nickel and/or manganese to retain their crystalline structure.

These stainless steels are named by their chromium and nickel content. The common composition of 18% chromium and 8% nickel is known as 18/8 stainless. 18/0 and 18/10 are also available.

The most common grade is Type 304, which is 18/8 stainless steel.

The second most common is Type 316, called "surgical stainless steel" for food and surgical stainless steel uses. In addition to chromium and nickel, surgical stainless steel also contains molybdenum to prevent specific forms of corrosion and help maintain the cutting edge. Three hundred sixteen surgical steel is used in the manufacture and handling of food and pharmaceutical products *where it is often required in order to minimize metallic contamination.*

Type 440 is used to make knives, as it holds a sharp edge well.
Content of Common Stainless Steels
Cr (Chromium), Ni (Nickel), C (Carbon), Mn (Manganese), Si (Silicon), P (Phosphorus), S (Sulphur), N (Nitrogen)

<table>
<thead>
<tr>
<th>SAE</th>
<th>% Cr</th>
<th>% Ni</th>
<th>% C</th>
<th>% Mn</th>
<th>% Si</th>
<th>% P</th>
<th>% S</th>
<th>% N</th>
</tr>
</thead>
<tbody>
<tr>
<td>304</td>
<td>18-20</td>
<td>8-10.50</td>
<td>0.08</td>
<td>2</td>
<td>0.75</td>
<td>0.045</td>
<td>0.03&lt;</td>
<td>0.1</td>
</tr>
<tr>
<td>316</td>
<td>16-18</td>
<td>10-14</td>
<td>0.08</td>
<td>2</td>
<td>0.75</td>
<td>0.045</td>
<td>0.03</td>
<td>0.10</td>
</tr>
<tr>
<td>440A</td>
<td>16-18</td>
<td>-</td>
<td>0.60-0.75</td>
<td>1</td>
<td>1</td>
<td>0.04</td>
<td>0.03</td>
<td>-</td>
</tr>
<tr>
<td>440B</td>
<td>16-18</td>
<td>-</td>
<td>0.75-0.95</td>
<td>1</td>
<td>1</td>
<td>0.04</td>
<td>0.03</td>
<td>-</td>
</tr>
<tr>
<td>440C</td>
<td>16-18</td>
<td>-</td>
<td>0.95-1.20</td>
<td>1</td>
<td>1</td>
<td>0.04</td>
<td>0.03</td>
<td>-</td>
</tr>
</tbody>
</table>

Mo

Leaching of Metals from Stainless Steel

Despite the fact that stainless steel has an outer protective layer that reforms almost immediately when the metal is scratched, iron and nickel do leach through this layer, resulting in the leached of all three metals into food and beverages.

I searched for studies that would show leaching of metals from stainless steel and found one that I could purchase for $34, so I bought it: Bulletin of Environmental Contamination and Toxicology: Leaching of Heavy Metals (Chromium, Iron, and Nickel) from Stainless Steel Utensils in Food Stimulants and Food Materials.

It's from 1994, but stainless steel is stainless steel.

They tested a variety of stainless steel tumblers and bowls used in India, some new and some used.
Foods of various pH were tested for the leaching of iron, chromium, and nickel.

<table>
<thead>
<tr>
<th>item</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distilled water</td>
<td>7.00</td>
</tr>
<tr>
<td>5% Sodium carbonate</td>
<td>11.50</td>
</tr>
<tr>
<td>5% Acetic Acid</td>
<td>2.11</td>
</tr>
<tr>
<td>Tea</td>
<td>6.65</td>
</tr>
<tr>
<td>Coffee</td>
<td>6.50</td>
</tr>
<tr>
<td>Milk</td>
<td>6.88</td>
</tr>
<tr>
<td>Curd</td>
<td>4.30</td>
</tr>
<tr>
<td>Fruit juice</td>
<td>4.20</td>
</tr>
<tr>
<td>Lemon pickle</td>
<td>2.55</td>
</tr>
</tbody>
</table>
Their findings:

- Iron, chromium and nickel were all found to leach into both alkaline and acidic foods and beverages, while none of the metals leached into distilled water.
- Leaching of iron, chromium and nickel was observed from both new and old utensils.
- Leaching of iron occurred in all foods.
- Leaching of nickel occurred in curd, fruit juice and pickle (more acid).
- Leaching of chromium occurred in milk, coffee, and tea (only slightly acid).

Thus, the study concluded "stainless steel utensils may put reasonable amount of iron and chromium trace element in diet. The concentration of nickel leach out in food products probably do not constitute hazard to consumer as the amount of nickel eleaced out is lower to that of recommended values of EPA (0.02 mg/day)."

It also noted, "There are many factors which probably effect the release of iron, chromium and nickel in food. These will include stainless steel surface area of contact, physical nature of surface area, pH of food products, its temperature, time and contact, agitation, chemical composition of steel alloy and presence of organic chelating constituents like citric acid, tartaric acid and oxalic acid."

> So there is a wide spectrum of possible leaching that could occur.

My philosophy is to apply the "precautionary principle" and avoid potentially toxic chemicals whenever possible. Since cookware and water bottles exist that do not leach these metals, I prefer to use and recommend those that do not leach toxic substances.

Here is a whole list of other studies that have data on the leaching of metals into food and beverages:


Food
Submitted by AEW on Thu, 11/05/2009 - 13:49.

Do have recommendations for what kind of stainless steel cookware would be best. Or should we just look for anything made with surgical steel?

COMMENT FROM DEBRA:
If you want stainless steel, use surgical steel.
I'm having trouble finding what your recommendation for reusable water bottles and containers is (as mentioned above). It is so frustrating to read that stainless steel isn’t necessarily a safe choice. I got rid of ALL my plastics and replaced them with stainless steel. It cost me a fortune. Now what do I replace my stainless steel with?

**COMMENT FROM DEBRA:**
Glass, glass, glass.

---

Thanks for that informative article! I have several products that are purported to be stainless steel such as a Klean Kanteen and a SIGG stainless steel utensil set that have formed a black or reddish tarnish in crevices where water gets stuck and on the bottle toward the bottom inside the neck. It comes off w/scrubbing and doesn't seem to corrode into the metal, but I can't help but think is rust. My husband thinks that it's just the weld/bonds or the screw (for the utensil set) that is rusting but the rest is stainless steel. Is this tarnish rust, and if not what is it and is it safe? Is there a way to prevent it or is it a defect? Does this mean that my item is not stainless steel?

**COMMENT FROM DEBRA:**
Stainless steel shouldn't get black or reddish tarnish. I don't know what it is you are experiencing. Contact the manufacturer.

---

Hi Debra,

What would be some stainless steel cookware brands and water bottles that DO NOT leach metals?

Thanks:

**COMMENT FROM DEBRA:**
I haven't checked to see what type of stainless steel different cookware and water bottles use. Type "surgical stainless steel cookware" into your favorite search engine and a number of brands will come up.
I made pickles for the first time this summer and now the finish is damaged/removed in places on the inside bottom of my stainless steel stock pot. What does that all mean? -- that it wasn't stainless steel in the first place (it was inexpensive)? Should I now buy a new pot?

**COMMENT FROM DEBRA:**
I think I'd buy a new pot. I've made a lot of pickles and the finish never came off my old stainless steel pots.

---

Hi

I was wondering what water bottle you would recommend? They are all plastic (not a fan) or stainless steel.

Thanks

Savanna Morrison

AB, CANADA

**COMMENT FROM DEBRA:**
Any glass bottle. I buy juice or soda bottles and empty the contents. These are usually more heavy-duty.

---

Debra, This is very interesting. Thanks for the article!

I thought stainless steel was one of the best cookware materials to use. Are there any better ones out there? (Le Creuset for example?)

As for water bottles, I guess glass would be the way to go?

Thanks

**COMMENT FROM DEBRA:**
Glass for water bottles. For cookware see Debra's List: Food: Cookware, with the exception of the stainless steel and tin-lined copper pots mentioned, which I will remove as soon as my computer allows.
ok, now I'm thoroughly confused about all this leaching business! we got rid of plastic water bottles, sippy cups and plastic lined coffee mugs in favor of stainless steel - is this now not the best option? What material is safest for these things?

**COMMENT FROM DEBRA:**
First, I've been writing in my books about stainless steel leaching for years. This is not new information. I just looked up the science on it to have first hand data instead of second hand data.

Clear glass is the safest material for water bottles and coffee mugs, and I don't know about sippy cups.

Please read what I wrote carefully. It says that contact time affects how much metals leach. If you had liquid in a sippy cup for two minutes, it's not likely to leach as much as simmering tomato sauce on the back of the stove all day.

---


Well, I'm confused - exactly what type of cookware & utensils do you recommend, that are easily available & affordable for the less affluent? I switched to stainless steel about 20 yrs ago, after reading that recommendation in Consumers Report magazine - they noted that aluminum cookware was leaching then, lol. So ever since, I've used everything stainless. Now, what to do?? I can't afford to buy a bunch of expensive special materials!

**COMMENT FROM DEBRA:**
My currently recommended cookware is at [Debra's List: Food: Cookware](#). There's a stainless steel pot I am going to remove when I solve my technical difficulties, and I'm going to remove the tin-lined copper pots as well. Otherwise, the rest stay.

---

Submitted by DAVE on Thu, 11/05/2009 - 14:01.

Thanks, this was extremely informative!
Hi Debra!

The information you put out there is so valuable! Thank you. I drink a lot of tea throughout the day. I don't have access to a stove where I work, so I was wondering what kind of electric tea kettle you would recommend. Hamilton Beach makes a stainless steel kettle with no plastic parts. It's the only one I could find, but given your recent post on stainless steel, do you know of something better?

**COMMENT FROM DEBRA:**
I don't know of a better electric tea kettle, but let me say that the amount of metals that leach from stainless steel has a lot to do with the amount of contact time the liquid has with the water. And remember, in the study there was no leaching from distilled water. So it's probably fine to heat your water in stainless steel for 5 minutes, which would be different from storing water for hours in a stainless steel water bottle. Even though there was no leaching measured in the study, water stored for any length of time in stainless steel tastes metallic, so there is some leaching there.

---

**Submitted by Lisa on Fri, 11/06/2009 - 05:29.**

I had heard that Le Creuset was the best cookware (cast iron with a ceramic finish) but I don't see it listed on your list, Debra. Why?

**COMMENT FROM DEBRA:**
First, just because something isn't on Debra's List doesn't mean there's something wrong with it. I may not know about it, or, recently, I haven't been able to add to Debra's List due to technical computer difficulties I am working on resolving.

As a point of fact, Le Creuset doesn't have a "ceramic" finish, it has an "enamel" finish. The difference being that ceramic is clay-based, like pottery, and enamel is a paint that dries to a very hard, usually glossy, nontoxic finish. I haven't recommended enameled cookware in the past because enameled cookware has been known to chip easily. However, I will reconsider this, as the enamel finish is not toxic after it is dried in the factory (the enamel paint itself is extremely toxic). Ceramic is not toxic throughout manufacture and does not chip.
Hi Debra, Excellent article. What evidence is there that iron and chromium are toxic? I know we need them in our diet. Are they different in the form that they are leached? Thanks for the great work!

COMMENT FROM DEBRA:
Chromium is one of the basic elements found on the Periodic Table of Elements. The toxicity of chromium varies according to its form. Trivalent chromium is actually required by our bodies in trace amounts for sugar metabolism (diabetics take it as a dietary supplement to lower blood sugar) and its deficiency may cause a disease called chromium deficiency. Hexavalent chromium, however, is very toxic and mutagenic when inhaled.

I don't know what form chromium is in when in stainless steel. Even if it is in its natural state, the study says, "Although iron and chromium are considered to be essential trace elements, excess exposure to chromium is known to cause dermatitis, bronchial asthma and ulcer and nickel is a toxic element and has been reported to exert variety of disorders even cancer." More on chromium toxicity at: www.corrosion-doctors.org/Pollution/chromiumtoxicity.htm

In addition, it is widely known that excess exposure to iron can be harmful to health (see www.irontoxicity.com and www.ironoverload.org).


Debra,
I wonder if you would be interested in something I read in "Mother Jones" (maybe in the 80s): Iron pipes used in pumping oil wells, were recycled into chain link fences — used in [i.e.] school yards, where a high percentage of school children 'mysteriously' developed cancer. A concerned parent, using a Geiger counter, discovered the cause: highly radiated crude debris clogging the pipes.

About 5 years ago I bought a set of stainless steel dinner ware, made in China, but was suspicious of using; wondering if the stainless had been recycled from who knows where.

Thank you for your continuing research. I have been a devoted reader since buying your 1st book years ago, teaching me to consider being suspicious of goods. I wonder how I could find a way to test my stainless, with a Geiger counter.
COMMENT FROM DEBRA:
Well, all stainless steel produced today contains some recycled material.

As to where to get a Geiger counter, try looking under "Laboratory Equipment" in your local Yellow Pages. Or call a lab and ask who does such testing.


Hi Debra,

A friend passed me your article. Good piece of information. However, I believe that since the study was done in India, it may have been done with sub-quality stainless steel. It is a possibility we should reflect on. I grew up in India and after I trained as a natural foods chef and ventured out for utensil shopping, I experienced finding plenty of sub-quality utensils including stainless steel utensils.

Even in the U.S., when I bought some stainless steel pans/mixing bowls at a restaurant supply store; it seemed to be of a poor quality than ones bought from reputed companies. Perhaps the quality may have contributed to the results from the studies.

regards,

Tarika


Glass water/drink bottles are best but what is the next best thing when glass is not practical or allowed. I'm thinking for water/ juice in kids lunches, etc. Many parks and pools don't even allow glass. Plastic, stainless steel, aluminum all have their problems and price differences but which is worse? I searched your site and all the info has my head spinning so please forgive me if this has already been answered.

COMMENT FROM DEBRA:
What about a glass Thermos bottle?


I'm not sure about the logic in a recommendation to avoid using all stainless steel products based on the study results posted in this blog. In fact, the findings by the study's authors state the amounts of trace metals found to leach (or migrate) from the
stainless steel utensils did NOT constitute a hazard. You wouldn't tell people to avoid whole wheat bread because it contains 0.68 milligrams of iron (Federal Dept. of Agriculture) and a microgram of chromium (National Institute of Health), would you? In addition, upper intake limits (e.g., the maximum daily nutrient intake likely to pose no adverse effects) for daily nickel consumption range between 200 and 1,000 micrograms, with children at the lower end and adults at the upper end (National Academy of Sciences). Lots of foods in the normal human diet contain small quantities of nickel and other metals.

It seems like what's important here is to know which substances might be transferred from a container/material made by a given company, and in what quantities, and ensure they don't pose a health risk. It is pretty simple internet research, or you can ask companies you purchase from, or consider purchasing from, to document that information for you. Once you have the whole picture, you can make informed, logical decisions about what types of materials or companies you can feel confident in purchasing from. In the case of stainless steel, it doesn't have to be all or nothing.

**COMMENT FROM DEBRA:**
This is a very good point. To me, what the study establishes is that metals DO leach. It is up to the individual to decide whether or not they are willing or able to put the amount of metals that leach into their bodies. Note I mentioned a number of factors that affect how much leaching occurs. Because of these variables, I don't think companies can give hard and fast data on how their cookware leaches. They could say we cooked tomato sauce and this is how much leached. Also, every body has an individual tolerance level and processes metals differently. Some bodies have high levels of metals that cause problems because of poor kidney and liver function. So it is a very individual choice that one would need to come to weighing many factors.

As a consumer advocate, I cannot make those individual evaluations. I can only state generally the data I have. Yes, I would agree one could probably selectively find stainless steel that might be right for you individually. I need to recommend the safest cookware that exists. Since surgical stainless steel is safer and ceramic is safer, as well as others, I recommend those.
COMMENT FROM DEBRA:
18/0

aw,
Please provide the model number of the Hamilton Beach tea kettle that has no plastic.
Thanks

Submit by Visitor on Tue, 01/25/2011 - 21:23.
I have All Clad stainless steel pots and pans; however, after reading about the leeching of stainless steel, I have purchased a couple pieces of the Xtrema cookware (on Debra’s list). Am I correct in assuming that this cookware is rated best and does not leech? What do we do about flatware? Is silver flatware best?

Submit by Debra Lynn Dadd on Mon, 01/31/2011 - 12:15.
Xtrema does not leach.
Personally, I use silver plated flatware, not stainless steel.

Submit by Stacey on Sat, 02/05/2011 - 22:19.
I see there is a great variation in price for silver-plated flatware. I assume that this might be due to the thickness of the coating of silver that is chemically bonded to the stainless steel. Does this matter? Is a cheaper, thinner layer of silver just as good as a more expensive silver-plated piece? I found a really cheap silver place set but am wondering if it is good enough before I replace my Stainless steel flatware...some of it can be very expensive! Thanks!

Submit by Debra Lynn Dadd on Tue, 02/08/2011 - 11:30.
One of the things about silver plated is that it does wear off with use. So a thicker layer would be better than a thinner layer. Also worn pieces can be replated.

Years ago I was able to find stainless thermos bottles lined with glass, but not anymore. Does anyone know of a brand that is lined with glass? Thanks. Barb P.


I have a severe nickel allergy (and have MCS) and yet have been using stainless steel for my water, cooking, etc for years. I wonder if that is one of the big things keeping me sick - nickel inflames my body fast!

Do you recommend the cookware that advertises on your newsletter?

http://www.ceramcor.com/

Trying to find an alternative and also something that will work on an induction stovetop!

thanks

Jill

Submitted by Debra Lynn Dadd on Mon, 01/31/2011 - 12:30.

Yes, that is one of the cook wares I use myself. It does not leach nickel.