Chemistry — an antidote to pseudoscientific thinking?

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Introduction

Knowledge of chemistry is a wonderful thing. It allows us to recognize and appreciate the many contributions chemistry has made to our modern way of life e.g., therapeutic drugs, new materials, safer foods, while also enhancing our understanding of how the world around us works. The ability to understand concepts such as kinetic theory, molecular structure, equilibrium, thermodynamics, and biochemical processes gives us a clearer picture of our world and can also help us make better decisions. It also has the potential to protect us from various forms of pseudoscience.

For those unfamiliar with the term, pseudoscience describes that which is portrayed as scientific but for which there is neither reliable evidence nor plausibility to support it. It is essentially "fake science". Examples of pseudoscience relevant to chemists include homeopathy, detox therapies, "bio-identical" hormones, various nutritional claims as well as many of the arguments used against fluoridation and climate change.

The effects of pseudoscientific beliefs are not always obvious, particularly for those of us working in academia, where such beliefs are less likely to be encountered. However, they exist and can cause harm in a number of different ways. An area of particular concern is health "treatments" based on pseudoscientific beliefs. Pain, injury and even death can result when such treatments are embraced as an alternative to effective medical interventions. Examples of fatalities resulting from pseudoscientific beliefs include the death of a nine-month old girl in Australia from septicemia and malnutrition when her parents chose to treat her eczema using homeopathy – her parents were subsequently convicted of manslaughter[1] – and the death of a New Zealand woman when a cancerous lesion was allowed to grow to occupy a large part of her head and skull while under the treatment of a naturopath.[2] The website, *whatstheharm.net*,[3] documents many other cases where belief in pseudoscience has had tragic consequences. So far over 300,000 deaths and a similar number of injuries have been attributed to such beliefs.

Pseudoscientific "treatments" can also be financially draining, particularly when they target the vulnerable, for example, a "detox" therapy at $70 per treatment with a recommendation that consumers have between 10 and 20 treatments.[4] The treatment was recommended for those suffering from a range of conditions including chronic fatigue, parasitic infections, arthritis, fibromyalgia and also as a post-radiation treatment. A description of how detox treatments are supposed to "work" is described in the next section.

Pseudoscientific beliefs can cloud public understanding of science, as demonstrated by ongoing public confusion over climate change and water fluoridation. This is a major concern. Informed decisions can only be made when people understand the relevant science. It is vital that scientists (including chemists) participate in such discussions and communicate the science clearly and effectively.

Chemistry-related pseudoscience

Pseudoscience relies on an ignorance of science and the scientific method to convince people that it works. A knowledge of chemistry can help spot the flaws in different pseudoscientific beliefs and products, effectively acting as an antidote. Some examples of chemistry related pseudoscience are outlined below.

Detox therapies

There are several different types of detox therapies, the most common of which involves placing one's feet in a warm salt water bath through which an electric current is passed. Within an hour the solution turns an orange brown colour which is claimed to consist of all of the toxins that have been pulled out of the body through the feet. A far more plausible explanation is that the electrodes placed in the water contain iron and that the discolouration is due to the iron salt produced in this electrolytic cell. This is a perfect example of how a knowledge of chemistry could help people avoid (and challenge) pseudoscience. A video explaining how this therapy is supposed to "work" can be found on Youtube[5] for anyone willing to sit through 10 minutes of the most excruciatingly painful misuse of science terminology!

Another less expensive detox therapy involves sticking pads on the bottom of one's feet overnight. By morning they will have turned a dark brown/black colour and smell awful. While those selling the pads claim this is the result of toxins pulled out of the body through the soles of the feet, a more scientific explanation is that the various compounds in the pads, including wood vinegar, absorb moisture from the feet overnight to produce the dark colour and pungent smell.

Homeopathy

Homeopathy is an alternative treatment that has been around for over 200 years, and has some high profile supporters including the British royal family. It is based on three interrelated beliefs:

1. The "Law" of Similars. The idea that something which causes similar symptoms to a disease can be used to treat the disease e.g., onion juice to treat conditions which cause teary eyes.
2. The more dilute a treatment is made, the more potent it becomes. Homeopathic treatments involve repeatedly diluting a substance by transferring 1 mL from a pre-

vious solution into 100 mL. Many treatments involve carrying out this process 30 times (to produce what is referred to as a 30C homeopathic solution). Of course a chemist will realise that once this dilution has occurred more than 12 times (a >12C solution) the chances of there being any of the original solution or active ingredient e.g., onion juice, becomes unlikely. Given that substances including arsenic and pus from an anthrax infected animal have been used in homeopathic solutions this level of dilution is somewhat reassuring.

3. After each dilution the solution is succussed (shaken) to supposedly transfer the properties of the original substance to the water molecules.

These beliefs make no sense based on what we now know about disease, how drugs work and basic chemical principles, so why do such beliefs persist? The first reason is that most people do not actually understand what homeopathy involves. A survey done in New Zealand about five years ago showed that over 90% of those surveyed thought it was some sort of herbal-based remedy. Simply explaining how homeopathy is purported to work is one way that its use could be discouraged. A second reason is that homeopathy was developed at a time when conventional medicine included treatments such as bloodletting and consumption of toxic mixtures containing arsenic and lead. Under such circumstances a treatment consisting of pure water would certainly be preferable! However, in the present day the decision to replace conventional and effective drugs with homeopathic remedies can have deadly results, with some homeopaths still recommending homeopathy as a viable alternative to antimalarial drugs and vaccines, and as a treatment for diseases such as cancer, dysentery and AIDS.

Miracle Mineral Solution (MMS)

Miracle Mineral Solution consists of a 28% sodium chlorite solution in distilled water which is "activated" with a food acid e.g., citric acid, before being taken orally. It has been sold as a treatment for a wide range of conditions, from acne to AIDS. It is sold largely via websites which use scientific misinformation to persuade consumers to buy it, for example by suggesting that because sodium chlorite works as a disinfectant (bleach) to kill micro-organisms externally then it must be effective internally. As well as being taken orally, MMS has been administered intravenously as a "cure" for cancer and as an enema to "treat" autistic children, an appalling example of how pseudoscience exploits the vulnerable and causes additional harm.

Vitamins and supplements

Vitamins and minerals are important for good health, but usually in trace amounts. Companies selling these products often distort the public's understanding of our need for vitamins and other supplements by suggesting that if a little bit of something is good for you, then a lot must be even better. Instead, excessive vitamin and supplement use typically results in very expensive urine.

People can be encouraged to think more critically about vitamin and supplement use by reminding them that they are just one of many types of substances needed for good health e.g., fats, oils, proteins, carbohydrates, and that with such substances there is usually an optimum dose beyond which there is no additional benefit, and even possible harm. Analogies can also be useful, for example asking if there would be any benefit in overfilling the oil in a car? It is also worth pointing out that for most people a well-balanced diet supplies all of our vitamin and mineral needs, while also providing other important nutrients, including fibre.

A more dangerous pseudoscientific view of vitamins and supplements is that they can be used as a "safe and natural" alternative to medicines, for example those who suggest that HIV can be effectively treated by use of vitamins and herbal remedies.

Herbal/natural remedies

Natural substances can possess potent medicinal properties. Indeed, many of our modern medicines were derived from research involving natural products. However, for every natural product which has been confirmed to have valuable medicinal benefits[6] there are countless others for which claims are made which have never been verified, or which have been disproven.

The use of natural medicines can be made more hazardous by the erroneous belief that if something is natural then it is automatically safe to use. When encountering such beliefs, it is worth pointing out that some of the most lethal toxins known to humankind occur naturally, for example botulinum toxin, strychnine and tetradotoxin (from the Puffer fish).

Faith in natural remedies, particularly when used instead of pharmaceuticals, often relied on a (unconscious) belief in vitalism – that substances derived from nature are somehow better than those made synthetically. Advocates of natural remedies may claim, for example, that vitamin C tablets made from natural materials are better than those which contain vitamin C which has been synthesized. Advocates of herbal medicines also ignore the fact that the dosage of beneficial compounds may vary significantly from batch to batch, and that as well as the beneficial compounds, herbal remedies may contain other less desirable compounds. Pharmaceutical preparations at least contain consistent and reliable doses of compounds which are known to be active.

Water fluoridation

The fluoridation of public water supplies has received great attention over the last year, largely due to the efforts of anti-fluoridation groups in regions such as Hamilton. There are many facets to this debate, and it is as much about societal values as it is about the science, for example is it reasonable to "mass-medicate" the population for the benefit of only some of the population?

Chemists can help bring some sense to the debate by clarifying the science behind fluoridation and also by countering poor arguments such as suggestions that fluoridation is a bad idea because fluorine is toxic and fluoridating agents are byproducts of fertiliser. Explaining that fluorine and fluoride are not the same, toxicity is dose dependent, and that just because something is a byproduct does not mean it is harmful can at least help keep the debate focused on more rational arguments.

How to spot pseudoscience

Pseudoscience seeks legitimacy by pretending to be science. However, because it has neither plausibility nor evidence to support it, it can be easy to spot, particularly for those trained in science. The following list outlines some of the ways to spot pseudoscientific beliefs.

1. Misuse of scientific terminology. Terms such as "quantum", "energy fields", "vibrations", "toxic overload" and "frequency" are often used to sound "sciency" while descriptions of basic science are just plain wrong, e.g., "electrolysis of water breaks the water molecule into H^- and OH^{+}" (this description was used by a company providing detox treatments).
2. Explanations are implausible. Toxins being "sucked out" through the soles of the feet, and water "remembering" what it has been in contact with i.e., homeopathy.
3. Evidence to support pseudoscience involves misrepresentation of legitimate science, poorly run "experiments", cherry picked evidence and anecdotes. Sometimes it is just made up.
4. May rely on dubious experts to support it.
5. Claims of conspiracy when challenged, e.g., the government (Big Pharma) is out to suppress the pseudoscientific "breakthrough".
6. Attacks legitimate science. When denied the hard earned legitimacy of science, advocates of pseudoscientific beliefs often try to discredit science and medicine.

How do we counter pseudoscience?

Pseudoscience flourishes where there is a lack of understanding of science so one way to fight pseudoscience is to engage more with the general public. This could include getting involved with and/or giving talks to groups such as Rotary, Probus, Zonta and U3A. For those whose talents lie more with the written word, articles for newspapers and magazines, letters to the editor or contributing to a science-based blog are ways to help people understand science.

Chemists, by the very nature of our training, can contribute to public understanding of a wide range of important topics including:

- Toxicity is dose dependent (1 ppt of DDT in milk is not something to panic about)
- Natural compounds are not always safe and synthetic compounds are not always unhealthy
- Fluoridation
- Climate change (properties and reactions of carbon dioxide, methane, etc.)
- The chemical implausibility of homeopathy and other pseudoscientific beliefs
- How drugs work

When engaging with the public it is important to avoid the stereotypes that advocates of pseudoscience often promote, such as that scientists are cold, disinterested and arrogant. Instead, communicating with enthusiasm, a genuine interest in your audience, and a sense of humour will provide an enjoyable time, not only for the audience but also for the presenter. A presentation's content and delivery should be tailored to the audience to address their interests and background – a presentation to a group of year 13 chemistry students would of course differ from one given to a Rotary group. Scientific terms should be used judiciously and defined if your audience is likely to be unfamiliar with them. Giving a clear and concise explanation of scientific terms is one way to engage and include an audience in the topic. Asking questions of the audience during a talk is another way to include them and can be used to gauge their current views on a topic. It can also be a good way to get them to reflect on and question their existing beliefs. Making time to answer questions after a presentation is not only polite but also provides the opportunity to clarify points that the audience may not have quite understood.

Pseudoscience in advertising

Pseudoscientific products rely on advertising to attract new customers and the Advertising Standards Authority (ASA) provides an effective way to challenge them when the advertisements make claims which cannot be substantiated. Complaints can be made online[7] and if successful require the advertiser to remove/rewrite the advertisement. So far I have laid 15 successful complaints against a range of companies including detox therapies, "chemical free" flea collars and BioMag magnetic underlays[8] (for claiming that they induce melatonin production!). All one has to do is state the claims which cannot be substantiated and, where possible, provide evidence to demonstrate that the claims are wrong.

Summary

Chemists have a unique perspective on the world around us, one which makes us less vulnerable to pseudoscientific beliefs. We need to share this knowledge and challenge pseudoscientific beliefs as not only are they capable of doing harm to individuals, they also can result in poor decision making at a societal level. By engaging with our wider communities in an enthusiastic and respectful way we not only discourage people from pseudoscientific beliefs, we simultaneously encourage a greater interest in chemistry and the other sciences.

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