CHLORINE & ITS CONSEQUENCES

Report By: Jacqueline Brazin

12.091 Medical Geology/Geochemistry
Dr. P. Ila
IAP 2006, 01/30/2006

INTRODUCTION

Chlorine and its consequences have a far more reaching effect in society that one may have imagined. Consider a soccer ball, powerade (sport drink), the human body, the ocean, table salt, and a bleach pen. What do all these items have in common? They are all composed of some form of chlorine. Chlorine is all-around us and can be found in various forms as evident by these few examples. G.E. Porter, Nobel laureate in chemistry said, "So it comes about that salt, sodium chloride, formed from these violently reactive and poisonous elements, is not only safe to eat, it is essential to life. And the element chlorine, seeking another electron wherever it can be found, . . . is a destroyer of life and a useful bacteria" [Ref. 8]. The increased prevalence of chlorine in our society cannot be reversed at this time. Therefore, it is important to understand how it will continue to impact our lives. This paper reviews critical aspects of chlorine, chloride and its compounds and the role it plays in the world.

Chloride

Chloride Function

The word chlorine comes from the Greek word *khloros*, which means greenish-yellow. Chlorine is element 17 on the periodic table and exists as a chloride ion (Cl^-) and as chlorine (Cl_2). The element chlorine is in Group VII on the periodic table and classified as a halogen because it is highly reactive, and therefore, can not exist as a monatomic molecule. Chloride and chlorine are not produced the same way and do not have the same effects on the human body. Chloride (Cl^-) is found in the form of salts such as NaCl and KCl. It maintains the electrical balance in the nervous system and is involved in intracellular and extracellular transport. Chlorine (Cl_2), on the other hand,

exists only in the form of a diatomic molecule. It is a product of the electrolysis reaction: $2NaCl + 2H_2O \rightarrow 2NaOH + Cl_2 + H_2$.

"Life evolved from water" [Ref. 1]. The ocean holds all of the chloride that we need. Chloride is formed as a byproduct of the electrolytes, K, Mg, and Na. "In its original form, chloride is formed from various rocks into soil and water by years of weathering process" [Ref. 3]. From there, it is transported to oceans or closed basins. Chloride is also found in the stomach as HCl, where it maintains the pH. Chloride is very important for human metabolic processes. "To function properly, organisms must actively pump sodium and chloride out of cells and actively take in potassium." [Ref. 1]. The biological functions of sodium, potassium, and chloride include controlling cellular properties such as osmotic pressure, membrane potentials, condensation of polyelectrolytes, and required ionic strength for activity [Ref. 1].

Chloride is also an essential mineral [Ref. 4]. "Chloride is the major extracellular anion maintained at a concentration of 100-110 mmol L^{-1} in that fluid." [Ref. 1]. "Like Na^+, there is no control over Cl^- absorption, and homeostasis is affected by renal reabsorption" [Ref. 1]. It represents 70% of the body's total negative ion content [Ref. 3]. The suggested amount of chloride intake is 750-900 mg/day [Ref. 3] As a main electrolyte in the body, it assists in conduction of electrical impulses. Chlorine is an electrolyte and a minor element making up 0.14% of the concentration of elements in the human body [Ref. 3, 4]. Another role of chloride in the body is to combine with hydrogen to form HCl, which breaks down proteins for absorption of other metallic minerals. It also maintains the electrical neutrality across the stomach membrane. With Na and K, chloride works well to keep all of our biological systems running smoothly.

Chloride associated diseases

Like every essential mineral, diseases can result if there is an abundant or deficient intake. Usually, diseases associated with chloride intake are rare. Chloride toxicity has not been observed in humans except for impaired NaCl metabolism [Ref. 3] This can be avoided by a healthy diet and an active lifestyle. Deficiency diseases are also rare, but alkalosis can occur if the blood becomes overly alkaline. It results from excess loss of sodium and is a life threatening condition. Some symptoms include loss of appetite, lethargy, and muscle weakness [Ref. 6]. Hypochloremia is another condition which occurs due to a deficiency of chloride. Symptoms can include water overload, wasting conditions, and heavy sweating [Ref. 7].

Chlorine

History of Chlorine

The history of chlorine is quite fascinating because it dates back to the beginning of American history. The Swedish chemist, Karl Wilhelm Scheele, discovered chlorine in 1774. For over two centuries, it has been used for many applications in advancing different scientific fields ranging from the disinfecting the water supply to developing improved medications. In 1826, silver chloride was used to produce images marking the first photography, and in 1847, chloroform was first used as an anesthetic. It was later found to be harmful to patient, and other anesthetics were used instead. In 1908, the Jersey City waterworks used chlorine to disinfect the water supply. As a result of the success of that program, the Department of Treasury called for all water to be disinfected with chlorine by 1918. This was one of the greatest applications of chlorine because drinking contaminated water was a major cause of death in the early twentieth century.

In 1912, polyvinylchloride (PVC) was invented without a purpose. B.F. Goodrich later marketed it and sold it as a shower curtain. In 1915, chlorine was first used as a weapon in World War I, and in 1922, chlorine was used as liquid bleach for the household. In 1933, Dow Chemical produced Saran (polyvinylidene chloride), and in 1949 it was marketed as Saran wrap. Throughout the 1990's, various forms of chlorine have been used for medicines and developing medical imaging techniques such as x-rays and similar devices. Today, chlorine can be found in bleach products used for laundry or in the individual household for cleaning purposes. It can be found in swimming pools and in the drinking water supply.

Facts about Chlorine

Chlorine is involved in many aspects of the world. Every year, 12 million tons are produced in North America [Ref. 9]. Economically, chlorine is very important. It supports 2 million jobs annually in the US [Ref. 9]. Chlorine makes up 25% of the yearly output of plastics. It is also used for medical products, packaging, and appliances/electronics. Chlorine is not replaceable in these products, and to date, there is no known alternative.

Chlorine isotopes

There are nine isotopes of chlorine, but only three are stable including ^{35}Cl, ^{36}Cl, and ^{37}Cl. ^{36}Cl is radioactive and can be used as a tracer to label compounds. Its half-life is 3.01×10^5 years. The molecular weight of chlorine is 35.45 g/mol because ^{35}Cl is the most abundant isotope making up 75.77% of chlorine's weight.

Routes of Exposure

Exposure to chlorine can occur via three routes: inhalation, ingestion, and dermal contact. Inhalation is likely to occur as a result of an occupational exposure. For example, this can be a problem for workers who oversee operations or handle chemicals involving the polymerization process of PVC. Ingestion can happen if the drinking water supply is contaminated from chlorine waste products because it is improperly discarded there. Chlorinated byproducts of chemical reactions at nearby plants can also penetrate the soil and get into the water. Dermal contact can happen when handling a polymer such as PVC during the polymerization process. It is extremely important to take proper safety precautions when working with chlorine or any of its related compounds. Harmful effects due to exposure to chlorine or its related compounds depend on the dose and the routes of exposure. Inhalation of chlorine irritates the respiratory system. At 3.5 ppm, the odor can be detected, and at 1000 ppm, inhalation can be fatal. The workplace regulations established by National Institute for Occupational Health and Safety (NIOSH) set the recommended exposure limit for chlorine to be less than 0.5 ppm, which is much lower than the amount at which it can be detected [Ref. 10]. Pulmonary edema can result from this exposure and the lungs may become more susceptible to other diseases such as carcinoma.

Chlorine Compounds

There are many different chlorine compounds. Some have aromatic rings with chlorine(s) as a side group. Chlorine compounds can also form as a result of byproducts from chemical reactions. "Adding chlorine to organic matter almost invariably increases one or more hazardous properties—persistence, toxicity or the tendency to

bioaccumulate. . .these chemicals dominate virtually all government lists of priority pollutants" [Ref. 8]. Below is a discussion of several of these chlorinated compounds.

Dioxin (Polychlorinated Dibenzo Furans (PCDF) and Polychlorinated Dibenzo Dioxins (PCDD)) is a chlorinated organic compound. It is a byproduct of vinyl chloride manufacture and can be produced from trash barrels, coal fired utilities, wood burning, metal smelting, and diesel trucks. "Dioxins do not break down to any appreciable degree in the environment; virtually all the tetrachlorodi-benzo-p-dioxin (TCDD) released in the environment will remain there…indefinitely" [Ref. 8]. The National Toxicology Program has classified dioxin as a known human carcinogen [Ref. 11]. It bioaccumulates in tissues because as an organochlorine it is more soluble in oil and fats than they are in water. Exposure can cause chloracne, diabetes, and cancer, which has been shown in laboratory animals.

Polyvinyl chloride production is also a hazardous process, and the workers have a high risk of an occupational exposure if they do not take the proper safety precautions. "In the late 1960s, Dr. John Creech and Dr. Maurice Johnson were the first to clearly link and recognize the carcinogenicity of vinyl chloride monomer to humans when workers in the polyvinyl chloride polymerization section of a B.F. Goodrich plant near Louisville, Kentucky, were diagnosed with liver angiosarcoma, a rare disease" [Ref. 12]. Vinyl chloride is a human carcinogen as shown by the International Agency for Research on Cancer [Ref. 13].

Another chlorinated compound is chloroform, a volatile chemical which can be found in any chemistry laboratory. At 990 ppm, exposure can result in dizziness and fatigue, and the vapors can depress the central nervous system. Liver and kidney damage

can occur at higher inhalation levels. NIOSH considers it to be a potential human carcinogen [Ref. 13].

Exposure to all these chemicals should be limited. If they are used, it is extremely vital to ensure that all safety precautions are taken. Additionally, chlorinated chemicals that are byproducts of reactions should be monitored daily to prevent any excess from being produced unnecessarily.

Summary

Chloride is essential for human metabolism and maintaining electrical neutrality in the body. It is most common in the salt form of NaCl. Chlorine is helpful and harmful to society. It is a dangerous gas that has high reactivity, and therefore cannot exist in just element form. Chlorine needs to be used in a way that poses no health risks. It is important to follow the exposure limits and wear the proper safety equipment to prevent unnecessary inhalation and dermal contact. Many chlorine compounds are also carcinogenic. These should be handled with extra precautions.

Prevention is crucial when handling any chemicals. Pay particular attention to the safety and toxicology reports of all chlorinated chemicals. It is a reasonable argument to want to remove chlorine from society because of the health hazards it poses. However, "elements cannot be banned. Elements simply are" [Ref. 8].

Conclusions

Imagine life without plastics. With that said, all forms of chlorine are important for humans to live and to facilitate their lifestyles. There are many ongoing research projects to determine the health effects of chlorine because it has become such a prevalent chemical in society. Many of these studies are conducted by National Toxicology

Program (NTP) and National Institute for Occupational Safety and Health (NIOSH) so that precise exposure limits and health effects can be determined.

References

1. Selinus, O. *et al.* Essentials of Medical Geology. *Elsevier Academic Press.* Boston. 2005.
2. Komatina, M. Medical Geology: Effects of Geological Environments on Human Health. *Elsevier Academic Press.* Boston. 2004.
3. http://www.traceminerals.com/research/chloride.html
4. Ila, P. "12.091 Medical Geology/Geochemistry Lecture Notes." IAP 2006.
5. http://www.epa.gov/ttn/atw/hlthef/vinylchl.html
6. http://www.nlm.nih.gov/medlineplus/
7. Thornton, J. Pandora's Poison. *MIT Press.* Boston. 2000.
8. http://c3.org/chlorine_what_is_it/chlorine_story2.html
9. http://www.osha.gov/SLTC/healthguidelines/chlorine/recognition.html
10. http://www.osha.gov/dts/chemicalsampling/data/CH_270375.html
11. http://en.wikipedia.org/wiki/Polyvinyl_chloride
12. http://www.osha.gov/dts/sltc/methods/organic/org075/org075.html