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Acidic and Basic Destruction of Tissues

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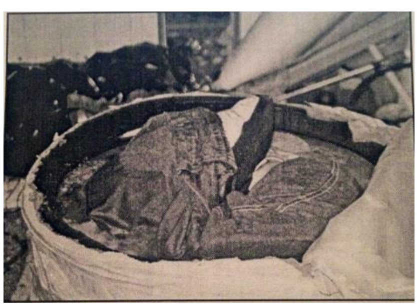
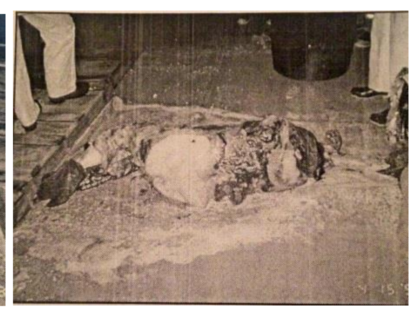
Abstract

A coroner's case I had learned about involved a man attempting to dispose of a body with acid. Shortly after exposure, the man was apprehended and the body was located. Upon investigation, police force determined the acid used to be hydrochloric acid, however, exact concentration remains unknown (Kohr, 2010). This led to the question of which easily accessible acid works best to degrade tissue. To answer this, an experiment was conducted involving pig feet and various concentrations of common acids and a single strong base. The feet were submerged in the solutions overnight and mass percent lost or gained was calculated. Analysis showed that hydrochloric acid did, in fact, destroy the tissue the most, but at its highest concentration. This proved our hypothesis of nitric acid degrading the tissues the most to be incorrect. The acid used by the perpetrator was most likely at a concentration between 6 and 12 M. More acid as well as a larger container would have proved him to be more successful.

Introduction

Last academic year, I received the opportunity to shadow a forensic pathologist in Terre Haute, Indiana. Reviewing previous interesting cases he had worked on, one was of particular interest. A young man had been reported missing, when shortly after, an informant overheard an individual boasting in a bar about how he disposed of a body in a container of acid. Police then investigated the report, leading the suspect's girlfriend to reveal the location of the body. A large waste can was discovered on the property that revealed the contents of a fully clothed body. An acid was used to attempt to dissolve the person, and therefore, hazmat suits were necessary to come in contact with the body until the acid was determined. The acid was later identified as hydrochloric which was stolen from a nearby facility. However, the exact concentration of the acid remains unknown (Kohr, 2010). Had a sample of the acid been taken at the time of discovery, laboratory testing could have been performed, and more information could have been found.





This case sparked an intriguing question and it was suggested by the pathologist that I carry out an experiment involving various acids to observe which one would cause the greatest amount of tissue destruction. Involved in forensics and biology, this is a topic of interest because it is useful to observe the effects of chemicals on the body. By conducting an experiment and documenting the progression of the chemical reactions, one could gain knowledge regarding the effects and apply that to a crime scene. This could give you some sort of idea as to what solvent was used prior to chemical testing, enabling you to take certain safety precautions immediately. To investigate the question of what solvent would inflict the most damage on tissues, the experiment was designed using pig feet and various concentrations of three acids and one base that could more easily be obtained commercially. The strong acids included Hydrochloric (HCl), nitric (HNO_3), and sulfuric (H_2SO_4) and the single strong base was sodium hydroxide (NaOH). The sodium hydroxide was used to simply compare its destruction to the acids, and see if it would have been better to use.

This topic was also of interest because disposing of bodies in acid or degrading tissues has become quite a popular topic in television shows and film. Oftentimes, the reaction is exaggerated and is not likely to occur at all. On television, one of the most talked about instances involving acid is the episode in which the two main characters of *Breaking Bad* are attempting to dispose of a body. The younger, foolish character disregards special instructions as to place the acid in a specific plastic container because the hydrofluoric acid (HF) will dissolve any other receptacle. He instead decides to pour the acid into a ceramic bathtub. The hydrofluoric acid eats through the tub as well as the floor, and everything crashes through the ceiling. The remnants of the body are sludgy and watery (“Hollywood acid,” n.d.). Hydrofluoric acid is extremely dangerous and corrosive. Even small amounts of highly concentrated HF can damage tissue or be fatal (“Facts,” 2013). The amount of acid used and the likely concentration that would dissolve a body could have killed the character in this episode. On another television series, *Mythbusters,* an experiment was done mimicking the television show. It was revealed that although the hydrofluoric acid would degrade the body some, it would not destroy the tissues completely. The tub and floor remained intact during the experiment as well. To corrode the ceramic bathtub along with the floor, a stronger acid would have been required (“Hollywood acid,” n.d.).

A newer crime drama is *The Blacklist* that features an episode titled, “The Stewmaker.” The name is not a farfetched description, as the serial killer is notoriously known for disposing his victims in acid, causing them to “disappear (Roman, 2013)”. A *Walker, Texas Ranger* villain even discarded bodies in this manner. Horror films, including the *Saw* franchise, oftentimes incorporate acids that torture or murder victims, however, the chemical reactions tend to occur more quickly and violently and are dramatized. *The House on Haunted Hill* shows a large aquarium the size of a swimming pool containing acid corrosive enough to dissolve bodies into skeletons (“Hollywood acid, n.d.). Hollywood uses chemicals in order to shock the audience with its effects; however, their interpretations are much more exaggerated and usually incorrect.

While gathering information about previously completed experiments in regards to acidic, or basic, tissue destruction, little was found. All chemicals should be handled with care and the proper safety guidelines should be understood when working with them. Due to nitric acid’s oxidative properties, meaning it gains electrons and is reduced during a reaction, it was hypothesized that nitric acid would destroy the tissues the most (“Oxidizing,” n.d., para2). Since it is a strong oxidizer as well as a strong acid, nitric acid could theoretically be the most destructive out of the three acids. It was then hypothesized that sodium hydroxide would decompose the tissues the second best since a 0.1 M solution has an extremely high basic pH of 13.0 out of a 14.0 scale. After NaOH would be hydrochloric acid with a low, strongly acidic pH of 1.1, and sulfuric acid following at a similar pH of 1.2 (“Acid-base pairs,” n.d.).

Upon researching the accessibility of these chemicals, it seems that for the majority of the acids and strong base used, they are easier to obtain than originally thought. HCl, H_2SO_4, HNO_3, and NaOH are all sold under different names and at more diluted concentrations. HCl is also known as muriatic acid, chlorohydric acid, hydrochloride, and spirits of salts. Muriatic acid has a concentration of 6 M is commonly used to balance pH levels in swimming pools as well as clean concrete and bricks (“Acid-base pairs,” n.d.). It is easily found at hardware stores, Lowes, Home Depot, and Walmart (Herr, n.d.). Companies have even attempted to produce muriatic acid that is safer, giving off fewer fumes, and are not as harsh on the environment, such as Klean Strip Green Muriatic Acid for example. Pure HCl is around 37.2%, whereas HCl sold commercially as muriatic acid or spirits of salts is diluted to 31.5% and 33%, respectively, but can vary. Depending on where the acid is purchased from and what it is used for, commercial HCl can be acquired for only $7-$30 (Hydrochloric acid, n.d.). H_2SO_4 is widely known as battery acid, hydrogen sulfate, and historically oil of vitriol. It can be purchased in automotive stores from 30-50% H_2SO_4 (Herr, n.d.). H_2SO_4 can also be found in drain cleaners to remove grease, hair, as well as certain fertilizers (Sulfuric acid, 2015). HNO_3 is also called aqua fortis, engravers acid, hydrogen nitrate, red fuming nitric (RFNA), and white fuming nitric acid (WFNA). RFNA and WFNA are both used as rocket propellant and are close to pure HNO_3 (Nitric acid, n.d.). The acid is also used to test metal. By placing gold substitutes into nitric acid, a reaction will take place; however, pure gold will not react. It is also being used in explosives such as trinitrotoluene (TNT), nitroglycerine, nitrocellulose and Semtex (Clegg, n.d., para 5,6). HNO_3 is most commonly found in fertilizer, specifically ammonium nitrate. This can be more difficult to obtain, depending on your location as it is found in rural areas, although some fertilizers containing nitric acid can be found at garden supply stores (Herr, n.d.). Ammonium nitrate can be purchased at Co-op and feed stores and potentially some hardware stores. The concentration of HNO_3 in fertilizers is higher, at 80% (Nitric, n.d.). Other names for NaOH include caustic soda, lye, soda lye, and sodium hydrate. NaOH is common in dissolving grease, oils, fats and proteins. It is generally found in drain cleaners such as Drano and liquid plumr, and oven cleaner. These products range from 30-50% NaOH (Sodium hydroxide, 2015).

Materials and Methods

To begin this experiment, pig feet were chosen as the specific tissue type to submerge in the solutions. The feet were halved in order to ensure there were enough for all of the solvents. Not only have pigs been used in skin grafts and valve replacements, pig skin have shown to be closest in similarity to the skin of humans. Epidermal thickness is comparable, as well as the ratio of epidermal and dermal thickness. Human and pig skin also have similar blood vessel and hair follicle arrangements. Collagen and elastic fibers found in the dermis of pigs also have more comparisons to humans than other animals used in laboratory testing (Herron, 2009).

Hydrochloric acid (HCl), sulfuric acid (H_2SO_4), nitric acid (HNO_3), sodium hydroxide (NaOH) and water were chosen to observe various levels of tissue destruction, with water being a control. HCl, as previously stated, was the acid used in the case. Sulfuric and nitric acids were selected due to their commercial availability and access and NaOH was a strong base chosen to see its comparison to the acids and if it would have been a better choice than the HCl. Three molarities, or concentrations, of each solvent were used to create a range of possible answers as to which acid or if the base would be most destructive and to observe the progression of each solvent. The molarities for each were as follows: HCl—1, 6, 12 mol/L (M); H_2SO_4—1, 9, 18 M; HNO_3—1, 8, 16 M; and NaOH—2, 5, 10 M. For the acids, the highest molarities used were each acid's most concentrated and pure molarity. Ten molar is not the highest concentration for NaOH, but is a fairly high molarity to use in this simple experiment. The pure molarities were halved for the second concentration, and 1 M was used for the weakest. The lowest concentration for NaOH, however, was 2 M due to mathematical error. The concentrations were prepared in 600 mL and 1 L beakers. Each foot was weighed in grams prior to exposure. Masses amongst the feet varied greatly, with a difference between the lightest and heaviest foot measuring 175.81g. The time was recorded as each foot was placed hoof up into a solvent and initial observations were documented, including color changes and if bubbling was present.

Only a few minutes after placing the foot into the 12 M HCl, the solvent had already began bubbling and the tissues were starting to discolor from red to light pink and brown. Gases from the acid were escaping from the top of the beaker. The 6 M HCl was also bubbling; however, it surprisingly had more bubbles than the 12 M. The color of the foot also began to change to light pink and brown. The least concentrated HCl, 1 M, had bubbles beginning to form, signaling a reaction was starting to take place, and the tissues and bone were again changing slightly from red to pink and brown. No gases were forming off of the 6 and 1 M.

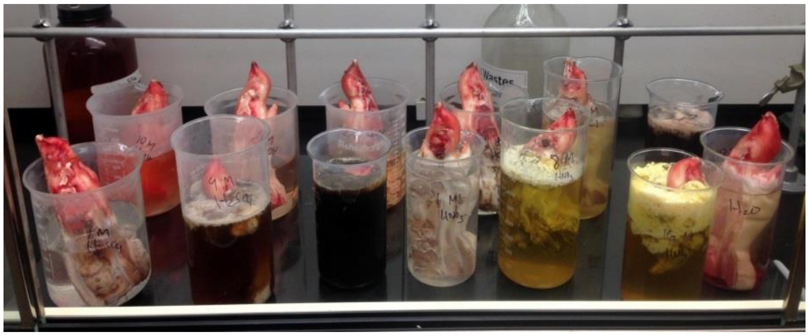
The foot placed in the 18 M H_2SO_4 quickly started to turn yellow and brown. Bubbles were actively moving and the tissues began to look unpleasant. Similar to the second concentration of HCl, the 6 M H_2SO_4 had more bubbles than the higher concentration. The tissues were also starting to turn light pink and brown. The 1 M was also comparable to the 1 M HCl, as bubbles were forming around the tissues, but were not floating to the top. The color changes were also the same with pink and brown discoloration.

The highest concentration of HNO_3 used displayed a more apparent reaction briefly after the foot was placed into the acid. The tissues quickly began to brown and turn a dark yellow. A few minutes later, white bubbles formed and were actively floating. Vapors were also visible above the solution. The 8 M HNO_3 modified the tissues a bright yellow and dark brown. Parts of the foot were still tinged red and changing to a lighter pink. Like the other lowest concentrations, the 1 M had bubbles forming amongst the tissues. The foot in this solvent, too, was somewhat browning and lightening to pink. No tissue destruction was beginning to show from any of these molarities.

The 10 M NaOH, its highest concentration, however, soon presented a cloudy solution. The pig foot was already beginning to decompose and degrade. Cohesion of the tissues to the bones was diminishing, and the entire foot had started to deteriorate. The 5 M NaOH did not show such a violent and rapid reaction. This foot was not changing much, with only a slight darkening of the bone. The 2 M NaOH, on the other hand, did in fact present more prominent changes. The tissue and bones appeared black and necrotic. Areas were also turning dark brown and yellow, and it appeared as if the strong base was attacking the fat within the foot, specifically. Water was simply used as a control and presented no initial changes; the foot remained a vivid red. The solutions were left undisturbed overnight.

The following day, starting at 1:49 P.M., each concentration of acid or base and their amount of tissue destruction was analyzed. As the remnants of each foot were removed from the solvents, the time was recorded. In order to handle the tissues and bone safely, neutralization was required. Neutralization is a process in which strong acids and strong bases react to form water and a salt. The H^+ and OH^- ions will combine to produce water ("Neutralization," n.d., para 1). To neutralize, the remainder of the foot was immersed in a solution of water and sodium bicarbonate with tongs before reweighing. To determine how much tissue destruction occurred, the mass percent loss was calculated.

Results



Acid/Base	M (mol/L)	m_1 (g)	m_2 (g)	t_1	t_2	% Mass Lost/Gained
NaOH	2	222.72	234.35	4:35	3:15	5.22
NaOH	5	285.79	264.05	4:34	3:12	-7.61
NaOH	10	354.59	289.16	4:33	3:04	-18.45
HCl	1	228.91	205.40	4:37	3:19	-10.27
HCl	6	327.15	261.17	4:39	3:23	-20.17
HCl	12	178.78	7.03	4:40	3:28	-96.07
H_2SO_4	1	288.72	268.99	4:42	2:30	-6.83
H_2SO_4	9	228.45	119.33	4:43	2:36	-47.77
H_2SO_4	18	302.47	80.03	4:44	2:12:00	-73.54
HNO_3	1	282.08	266.99	4:46	2:44	-5.35
HNO_3	8	293.38	167.13	4:46	2:50	-43.03
HNO_3	16	271.74	94.11	4:48	2:55	-65.37
Water	N/A	279.85	270.89	4:50	3:01	-3.20

After calculating the percent mass lost for each foot, it was found that 12 M HCl presented to have the most tissue degradation with a mass percent loss of 96.07%. The foot initially weighed 178.78g and was dissolved down to a few bones, weighing only 7.03g. The hoof was not visible above the solution and foam of white and brown bubbles had formed. The once clear and transparent solution became dark black and opaque; therefore, no tissue and bone were visible in the solution, although some remnants were floating at the top.

The second concentration to degrade tissue the best was 18 M H_2SO_4 with 73.54%. This foot's hoof was almost entirely submerged in solution. Similar to the solution of the 12 M HCl, its color had changed from clear to black. Tissue was visible at the bottom and on the sides of the beaker. Brown and black bubbles were also present.

The next destructive acid was the highest concentration of HNO_3, 16 M, with a mass percent loss of 65.37%. The results showed that this reaction was much more vehement than others. The hoof had begun to fall into the solution but was present. The foam created on top resembled that of scrambled eggs, in color and texture. The pig's foot was mangled, yet remained intact. Yellow and white bubbles were present and the solution was dark yellow and tinged brown.

Following was 9 M H_2SO_4 with 47.77%. The foot's hoof was visible, but had sunken down into solution. Foam with white bubbles was visible at the top, with some tissue that had separated from the foot. The solution was dark brown; however, tissue and bone were still visible, with white particles settling on the bottom of the beaker. Bone was also beginning to disintegrate.

Next was 8 M HNO_3 at 43.03%. This hoof too was above the solution, which was dark yellow and brown, and transparent. White and yellow foam was progressing, similar to that of the 16 M HNO_3. Tissue above the solvent line was damaged as well. The tissues and bone suspended in solution were dark brown, yellow and white. As the 16 M HNO_3 was mutilated, yet still cohesive, the 8 M was as well. However, with both feet, when removed for neutralizing, began to fall apart into pieces.

Six molar HCl was next at 20.17% mass lost, which was almost 20% less than the previous acid. Unlike the 12 M HCl, this concentration did not dissolve the hoof as it was still visible above the solution. The acid was cloudy, but the foot was still easily identified, with only some degradation. Some flesh was floating as well as resting on the bottom of the beaker, with bubbles present. The hoof itself had some discoloration, changing from pink to slightly browned and blackened. The tissues and bone turned from red to light brown, pink and white.

The next solvent to destroy tissue was 10 M NaOH, the strong base. Its percent mass lost was close to that of the 6 M HCl, with a value of 18.45%. The hoof was again above the solvent line. This solution was cloudy, but was more orange and pink colored than the other solutions. The foot had continued to fall apart after initial observations, and bones were in the bottom of the beaker. Tissue degradation was apparent, but appeared to be worse while the foot was in solution.

The lowest concentration of HCl, 1 M, had a percent mass lost nearly 10% less than the NaOH, with 10.27%. Not much degradation occurred at this molarity, as the tissues held together well. This solution, unlike the others, remained clear and colorless. Discoloration occurred on the foot above the acid, turning brown. The rest of the foot also changed colors, from red to shades of brown and white. The tissues also appeared to bulge and push away from the bones.

The middle molarity of NaOH, 5 M, was next with a percentage of 7.61%. This concentration did not react much with the tissues. The foot lightened somewhat in color, and its solution was light pink and clear. One molar H_2SO_4 was only about a gram less at 6.83%. The foot was hardly degraded, although the skin was slightly wrinkled. The tissues presented a color change from red to light brown and white. The second to last percent mass lost was the 1 M HNO_3 with 5.35%. Again, not much tissue destruction took place, with only a few particles on the bottom. This foot was also light brown and white in areas and its solution was clear. The smallest percent loss was 3.20% for water. The solution was red and bloody, but clear. Little discoloration was present, and no degradation took place. A solvent unlike all the others was 2 M NaOH. Instead of losing mass, the foot gained 5.22% after exposure. The solution was yellow but transparent. The tissues had started to pull away and decompose. The bone discolored more, turning black, dark brown, and yellow.

Conclusion

The initial observations suggested that HCl, the presumed acid used in the homicide, would have one of the least mass percent loss. The 12 M was actively bubbling which represented a reaction was taking place; however, both pure H_2SO_4 and HNO_3 had more discoloration and tissue destruction. Therefore, it was a surprise to find it had nearly dissolved the entire foot the following day and destroyed tissues the most. This proved our hypothesis to be entirely incorrect. It was not much of a surprise to find that the concentrations of the solvents were the highest, although the two solvents that were chosen to destroy tissue the most, HNO_3

and NaOH, did not have considerably high percentages of mass lost. The nitric acid, however, did react more than the sodium hydroxide as it had two of the three concentrations in the top five. The thick foam that developed in the 16 M HNO_3 could have held the rest of the foot in place, preventing it from dissolving more in the highly concentrated acid. The H_2SO_4 destroyed tissues exceptionally well as its two high concentrations were second and fourth in percent mass lost. The concentration of HCl used by the suspect was most likely between 6 and 12 M since muriatic acid is publicly sold at 6 M and the acid he used was stolen from some sort of chemical plant.

Briefly after submerging the feet, 10 M NaOH seemed as if it would present a large amount of damage to the tissues, as cohesion rapidly diminished. After reweighing, the highly concentrated NaOH only lost 18%. This result was not expected as well, since NaOH is a fairly strong base. It is unclear as to why the 2 M NaOH would have gained in mass rather than decrease. A possible explanation is there could have been an error with the balance when weighing. Therefore, in answering one of the starting questions, the NaOH did not destroy the tissues as much as anticipated and would not be a wise choice to use to decompose flesh in comparison to a strong acid. Ten molar is not the highest concentration of NaOH that could have been used in this experiment. The highest molarity for NaOH is 18.9 M, which is much more concentrated. To obtain this extremely high molarity of NaOH would be rather difficult, and is not found commercially. It would, however, be interesting to see what effects other strong bases would have on the tissues.

Due to the victim's larger size and having been fully clothed, the rate at which the tissues decomposed was rather slow. The container the young man had been placed in was too small, leaving little room for the acid. The amount of acid poured into the waste can was also not enough to dissolve the body. After conducting this experiment, it is shown that a concentration between 6 and 12 M HCl would destroy tissue in a reasonable amount of time. Had the perpetrator chosen a larger container and used more acid, as well as without confessing to his crime while intoxicated, he might have been successful in disposing of the body.

References

Acid-base pairs, strength of acids and bases , and pH. (n.d.). Retrieved from http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch11/conjugat.php

Clegg, Brian. (n.d.). Chemistry in its element—nitric acid. Retrieved from http://www.rsc.org/chemistryworld/podcast/CIIEcompounds/transcripts/nitric_acid.asp

Facts about hydrogen fluoride (hydrofluoric acid). (2013, April 22). Retrieved from http://www.bt.cdc.gov/agent/hydrofluoricacid/basics/facts.asp

Herr, Norman. (n.d.). Equipping the laboratory. Retrieved from https://www.csun.edu/science/ref/equipment/acquisition/common.htm

Herron, A. J. (2009). Pigs as dermatologic models of human skin disease. *IVIS*. Retrieved from www.ivis.org/proceedings/acvp/2009/Herron.pdf?LA=1

Hollywood acid. (n.d.) Retrieved from http://tvtropes.org/pmwiki/pmwiki.php/Main/HollywoodAcid

Hydrochloric acid. (n.d.). Retrieved from http://pubchem.ncbi.nlm.nih.gov/compound/hydrochloric_acid#section=Top

Kohr, R. (2010). *A single barrel acid trip* [PowerPoint Slides].

Neutralization. (n.d.). Retrieved from http://chemwiki.ucdavis.edu/Physical_Chemistry/Acids_and_Bases/Acid%2F%2FBase_Reactions/Neutralization

Nitric acid. (n.d.). Retrieved from http://www.cdc.gov/niosh/npg/npgd0447.html

Nitric acid (n.d.). Received from http://pubchem.ncbi.nlm.nih.gov/compound/nitric_acid#section=Consumer-Uses

Oxidizing and reducing agents. (n.d.). Retrieved from http://chemwiki.ucdavis.edu/Analytical_Chemistry/Electrochemistry/Redox_Chemistry/Oxidizing_and_Reducing_Agents

Roman, Nick. (2013, October 15). The Blacklist—recap: acid wash keen. Retrieved from http://www.rickey.org/blacklist-season-1-episode-4-recap-review-stewmaker/234671/

Sodium hydroxide. (2015, February 13). Retrieved from http://www.cdc.gov/niosh/npg/npgd0565.html

Sulfuric acid. (2015, February 13). Retrieved from http://www.apastyle.org/learn/faqs/web-page-no-author.aspx