Pennsylvania
Department of Health

Public Swimming & Bathing Places (Aquatic Facilities)

Operational & Biological Contamination Protocol Recommendations

Pennsylvania Department of Health
Bureau of Community Health Systems
Division of Environmental Health Services
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Introduction

This document is designed to provide updated recommendations for public swimming and bathing place (aquatic facility) operations and contamination protocols. A set of recommendations for aquatic facility operations is in Chapter 1. Contamination protocols for the treatment of weekly bacteriological test failures and accidental fecal releases are in Chapter 2. Chapters 1 and 2 provide a set of instructions that is readily usable during field operations. Chapters 3 through 10 provide the rationale behind the recommendations outlined in Chapters 1 and 2.

The recommendations contained within this document are the result of data driven analyses of recreational and competitive aquatics. This information will have a direct, positive impact on millions of Pennsylvanians and visitors by increasing their safety and reducing their risk of exposure to Recreational Water Illnesses (RWIs) while swimming at Pennsylvania aquatic facilities. Based on Centers for Disease Control and Prevention (CDC) data, outbreaks of RWIs, particularly *Cryptosporidia*, have increased significantly nationwide in recent years. Outbreaks of *Cryptosporidia* in Pennsylvania were consistent with the national increase. Thus, the Pennsylvania Department of Health is addressing the issue of RWIs by formulating this set of protective recommendations for use at Pennsylvania aquatic facilities. Please keep in mind that each facility is unique. Managers will have to determine for themselves how to employ these recommendations to maintain their facility in a safe and healthy manner while remaining in compliance with state and local regulations.

For additional information on operational considerations and regulatory requirements, consult the Pennsylvania Public Bathing Place Law and Pennsylvania Code Title 28 (Health and Safety), Chapter 18 (Public Swimming and Bathing).

Other useful information on pool operations and safety can be found at The Pennsylvania Department of Health Website pertaining to public bathing places Bathing Places | Department of Health | Commonwealth of Pennsylvania and Centers for Disease Control and Prevention at Healthy Swimming | Healthy Swimming | CDC.

CHAPTER 1: STANDARD OPERATING RECOMMENDATIONS

The following recommendations are designed to provide the most effective operational parameters and management techniques for aquatic facility operators. When employed in the field, these recommendations will protect public health while controlling disease and increasing safety and bather comfort.

- **Warning:** Chemical levels must be maintained within United States Environmental Protection Agency (USEPA) limits during open hours:
  - USEPA chemical ranges are written on labels located on the chemical containers
- Alkalinity ideal range 80-120 ppm tested and logged at least weekly.
- pH ideal range 7.2-7.6, tested and logged at least twice daily.
- Residual Bromine ideal range 4-8 ppm, maximum 10 ppm, tested and logged at least twice daily:
  - Bromine is commonly used as a disinfectant in spas and indoor units. Bromine does not form the odors associated with chlorine and is more powerful than chlorine at higher pH levels and temperature ranges.
- Residual Free Chlorine ideal range 2-4 ppm, maximum 5 ppm, tested and logged at least twice daily.
- Combined Chlorine maximum 0.2 ppm, tested and logged at least twice daily:
  - Daily superchlorination for spas and wading pools
  - Weekly superchlorination for other pools
  - Keeping combined chlorine below 0.2 ppm through regular superchlorination treatments results in optimum disinfectant strength and the elimination of chloramines that degrade air and water quality
  - Superchlorination is achieved by increasing the free chlorine residual to ten times the combined chlorine level
  - Combined chlorine = Total Chlorine - Free Chlorine
- The use of Cyanuric Acid, stabilizer, trichlor, and dichlor is not recommended in Pennsylvania aquatic facilities:
  - Cyanuric acid can cause adverse human health effects and can eliminate chlorine's effectiveness against Cryptosporidia.
- Restock fresh test kit reagents annually.
- Pool Operators should be Aquatic Facility Operator (AFO), Certified Pool Operator (CPO), or other approved program certified.
- Operator changes should be reported to the Department of Health.
- Protective and informational signs should be posted, including but not limited to:
  - "Shower before swimming"
  - "Do not use the pool if you have had diarrhea within the last two weeks"
  - "Do not drink the pool water"
- Communicate to patrons and staff about recreational water illnesses (RWIs)

Table 1: Regulatory Standards vs. Recommendations

	Regulatory Standard	Recommendation
Alkalinity	No standard currently	80-120 ppm
pH	7.2-8.2	7.2-7.6
Bromine	Minimum residual of 0.8 ppm	4.0-8.0 ppm, maximum 10 ppm
Free chlorine	Minimum Residual of 0.4 ppm	2.0-4.0 ppm, maximum 5 ppm
Combined chlorine	No standard currently	Super chlorinate if combined chlorine levels exceed 0.2 ppm
Cyanuric acid	No standard currently	Not recommended for use at aquatic facilities
Testing	Disinfectant, twice daily pH, twice daily Bacteriological, weekly	Also test combined chlorine, twice daily Alkalinity, weekly
Testing kits	Chorine or bromine kit shall be accurate to within 0.1 ppm pH kit shall be accurate within 0.2 pH units	For disinfectants, use the DPD method (Diethyl-P-Phenylene Diamine) For pH, use the phenol red colorimetric method
Turnover	8 hours for general purpose pools 2 hours for wading pools	6 hours for general purpose pools 1 hour for plunge pools 4 hours for wave pools 2 hours for zero-depth entry areas, lazy rivers, wading and spray pools. 30 minutes for spas

Important Additional Regulatory Standards:

- Weekly bacteriological tests required for total coliform bacteria by regulation:
  - Samples fail at > 2 colonies per 100 ml sample
  - Contamination exists when more than two colonies of total coliform bacteria are detected in a 100ml sample of aquatic facility water
  - To correct contaminated water, refer to Chapter 2, Part 1: Formed Stool and Weekly Bacterial Test Failure Treatment
  - Weekly laboratory reports and monthly logs of twice daily residual disinfectant and pH must be kept on site for at least two years by regulation
- By regulatory requirement, Category 24 certification through the Pennsylvania Department of Agriculture (PDA) must be obtained prior to administering pesticides including chlorine, bromine, and algicides to public aquatic facilities.

CHAPTER 2: CONTAMINATION PROTOCOL

Part 1: Formed Stool & Weekly Bacteriological Test Failure Treatment

1. Close the aquatic facility including all units that share the same water
2. Communicate to patrons about the length and nature of closure
3. If applicable, manually remove fecal matter and dispose of it in sanitary facility. **Do not use the vacuum!**
4. Disinfect the removal device
5. Bring cyanuric acid level to less than 15 ppm by partial water changes
6. Bring pH to 7.2-7.5
7. Ensure combined chlorine level is less than 0.2 ppm
8. Maintain 5-10 ppm residual free chlorine for 30 minutes
9. Bring water chemistry back to recommended operational levels
10. Log the events, date, remedial procedures, pH, and chemical levels used during enhanced treatment
11. Reopen the unit(s)

Part 2: Unformed Stool & Cryptosporidia Treatment

Unformed stool or diarrhea material is an indication that a person with an infectious disease of the digestive tract has used the pool. Some of these infectious diseases or recreational water illnesses can be resistant to free chlorine. Cryptosporidia are the most chlorine resistant of the known organisms that cause recreational water illnesses. As such, higher levels of chlorine should be used to ensure that Cryptosporidia and any other less chlorine resistant organisms that cause recreational water illnesses are neutralized. This can be accomplished by following the instructions below:

1. Close the aquatic facility including all units that share the same water
2. Communicate to patrons about the length and nature of closure
3. If applicable, manually remove fecal matter and dispose of it in sanitary facility. **Do not use the vacuum!**
4. Disinfect the removal device
5. Bring cyanuric acid level to less than 20 ppm by partial water changes
6. Bring pH to 7.2-7.5
7. Ensure combined chlorine level to less than 0.2 ppm
8. Bring residual chlorine to 20 ppm then maintain 20 ppm for 12.75 hours or follow the recommendations in the following Table 2 (broadcasting calcium hypochlorite is the fastest way to reach high shock chlorination levels)
9. Check and record pH and free chlorine at least hourly during enhanced treatment and maintain at recommended levels
10. Bring water chemistry back to recommended operational levels
11. Log the events, date, remedial procedures, and hourly pH and chemical levels used during enhanced treatment
12. Reopen the unit(s)

Table 2: Cryptosporidia Chlorination Times

Chlorine Level (ppm)	Chlorination Time (CT) At pH 7.5
1.0	15,300 minutes (255 hours)
10.0	1,530 minutes (25.5 hours)
20.0	765 minutes (12.75 hours)

To determine how long it takes to disinfect Cryptosporidia at a particular ppm, follow this formula:

15,300 ÷ X ppm = time in minutes

15,300 ÷ 5 ppm = 3,060 minutes (51 hours)
15,300 ÷ 15 ppm = 1,020 minutes (17 hours)
15,300 ÷ 20 ppm = 765 minutes (12.75 hours)

Table 3: Recreational Water Illnesses vs. Chlorination Times

Recreational Water Illness (RWI)	Type of Microbial Pathogen	Method Of Transmission	Incubation Rates to Express Symptoms	Inactivation Rates: Chlorination Time (CT) @ 1ppm Free Chlorine and 7.5 pH
Escherichia coli	Bacteria	Swallowing contaminated water	3 days	Less than one minute
Shigella	Bacteria	Swallowing contaminated water	12 to 15 hours	Less than one minute
Pseudomonas	Bacteria	Direct skin contact with contaminated water.	8 hours to 5 days	Less than one minute
Giardia	Parasite	Swallowing contaminated water	1 to 2 weeks	45 minutes
Norovirus	Virus	Swallowing contaminated water	1 to 2 days	60 minutes
Cryptosporidia	**Parasite**	**Swallowing contaminated water**	**2 to 10 days, Median 7 days**	**15,300 minutes, Nearly 2 weeks**

The Pennsylvania Department of Health recommends following the Formed Stool & Weekly Bacteriological Test Failure Treatment protocol in Chapter 2, Part 1 and a closure of at least 30 minutes at 5-10 ppm residual chlorine during enhanced chlorination treatment after a weekly bacteriological test confirms total coliform or any other biological contamination except for Cryptosporidia. For Cryptosporidia treatment, follow the more protective recommendations found under Unformed Stool & Cryptosporidia Treatment recommendations in Chapter 2, Part 2. Please note that when using proper aquatic facility operations, weekly bacterial test failures and contamination will be virtually eliminated.

CHAPTER 3: FACTORS THAT AFFECT WATER CHEMISTRY

There are a multitude of chemical, biological, and electrical activities taking place in the water of an average, aquatic facility. Thus, aquatic facility operators must manually conduct accurate, comprehensive, and frequent testing of the water while maintaining thorough records and fresh test kit reagents to obtain a complete picture of the unique activities occurring at facilities over time. The following categories describe some of the major contributors to changes in water chemistry.

Human: Skin cells and fecal bacteria; body oils (natural and artificial oils, such as suntan oil); ammonia from human sweat and urine; dirt; chewing gum; food.

Environmental: Acid rain; atmospheric interaction; air/water temperature; air pollution; algae and fungi; chemical gases formed in the water; geographic location; humidity; sun; evaporation; dust; pollen; detritus; leaves.

Construction/Maintenance/Sanitation: Backwash frequency; chemical condition; construction materials; disinfectants; draining; filter media effectiveness and type; splash out and the makeup water quality and chemical characteristics; test kit reagent quality.

Biological: Bacteria and other microorganisms prefer a warm, moist environment with an adequate food source, thus a poorly operated swimming pool is an ideal place for them to inhabit. Water is an excellent environment for the transmission and growth of microbial organisms, including those that cause Typhoid and Paratyphoid Fever, Amoebic and Bacillary Dysentery, Hepatitis A, Pink Eye (Conjunctivitis), Schistosomes (Swimmer's Itch), Plantar Warts, Athlete's Foot, Shigella, Norovirus, Escherichia coli, Adenovirus, Pseudomonas aeruginosa, Legionella pneumonophila, Molluscipoxvirus, Giardia, and Cryptosporidia to name a few. Without proper disinfection, microbial colonies are continually increased through shedding by humans.

With all of this potential microbial and chemical activity, it becomes clear that regular monitoring of the pool water along with regular and necessary chemical adjustments in alkalinity, pH, and residual disinfectant levels, is vital to maintaining the facility in a healthy and safe manner. The information in the following chapters will provide pool operators and managers with a basic understanding of the nature of pool water chemistry. This knowledge is critical to understanding the various techniques and chemicals that are used to maintain good water quality conditions and protect the health of swimmers by eliminating microbial pathogens.

CHAPTER 4: ALKALINITY

It is recommended that aquatic facility water should contain between 80 and 120 ppm of total alkalinity. This is the best range of alkalinity to control the pH at the optimal range of 7.2-7.6. Testing weekly for total alkalinity and the subsequent addition of bicarbonate soda or muriatic acid is the best procedure for maintaining the proper alkalinity level. The alkalinity of water is expressed in terms of mg/L or ppm of calcium carbonate determined by titration. At high alkalinity levels the water begins to taste salty and will result in locking the pH at a level above operational standards while reducing the power of the disinfectant. At this point the alkalinity must be reduced to properly maintain the pH. It is also important to remember that low alkalinity can produce rapid changes in pH in either the acidic or basic direction due to bather load, chlorine, temperature, or other extraneous variables.

Disinfectants such as bromine, trichlor (Trichloro-S-Triazinetrione), and dichlor (Dichloro-S-Triazinetrione) tend to reduce pH and alkalinity over time. Total alkalinity can be increased by adding enough sodium bicarbonate (bicarbonate of soda, better known as baking soda) to the water to raise the level to a range of 80-120 ppm. If the total alkalinity is less than 80 ppm, it can be raised approximately 10 ppm per 10,000 gallons of pool water by adding 1 ½ pounds of sodium bicarbonate for each 10,000 gallons of water until the desired level is achieved.

An alkalinity level above 120 ppm will result in the pH becoming difficult to adjust and drive the pH to the high end of the range at potentially noncompliant levels. Disinfectants such as sodium hypochlorite and calcium hypochlorite tend to increase pH and alkalinity over time. This results in weakened disinfection and reduced bather comfort. Total alkalinity can be reduced by adding muriatic acid or sodium bisulfate. It is critical to keep the alkalinity between 80-120 ppm because this will help to buffer and stabilize the pH at the desired range of 7.2-7.6, while having the added effect of optimizing disinfectant power. The most effective techniques to provide substantial reductions in alkalinity are "columning muriatic acid" and partial water changes. Manual addition of acids will also reduce the pH level and must be carried out while the pool is closed to swimmers.

CHAPTER 5: pH

One of the main factors in aquatic facility water chemistry is pH. This is because of the role pH plays in enhancing disinfection and bather comfort. Alkalinity is the most important factor to pH as discussed earlier. Pure water is a neutral substance with a pH value of 7.0. All substances have a pH value that can be measured. All pH values below 7.0 are acidic. All pH values above 7.0 are basic. Acid properties of water are due to the presence of hydrogen ions, written as H^+. Basic properties of water are caused by hydroxide ions, written as OH^-. Water (H_2O or HOH), is constantly breaking up or dissociating into equal numbers of hydrogen and hydroxide ions. Since the number of each is equal, pure water remains neutral. However, pure water is never found outside of a controlled setting because it readily reacts with carbon dioxide in the atmosphere to form carbonic acid and drives the pH toward acidity. Rain therefore has a pH of nearly 5.75. Water being the "Universal Solvent" also reacts with a host of other chemicals, all of which affect the pH to some degree.

Strong acids and bases have corrosive properties and are hazardous. Adding an acid such as hydrochloric acid (also known as muriatic acid) to pool water will increase the hydrogen ion concentration and drive the pH down. Adding a base such as soda ash to pool water will neutralize some of the hydrogen ions and drive the pH up.

pH Recommendations

A pH range of 7.2 to 7.6 should be maintained to provide aquatic facility operators with the best results in bather comfort, longevity of equipment, and economical and effective disinfection. **The pH of the water must be tested to 0.2 pH units per state regulation.** High pH readings (above 7.6) should always be avoided. The most important factor related to high pH is the negative effect it has on the formation of hypochlorous acid (active chlorine). Thus, the higher the pH, the more chlorine it will take to maintain proper disinfection in the water and increase the cost of operations and potential for outbreaks. Conversely, if the pH is allowed to drop below 7.2, damage to metal surfaces, skin irritations, and excessive chlorine odors may be noticed. The effects of low and high pH are summarized in Table 4 below.

Table 4: pH Effects

Results of Low pH (below 7.2)	Results of high pH (above 7.6)
• Excessive chlorine odor • Metal corrosion, leading to leaks in all metals in contact with the corrosive water • Skin, tooth, eye, and mucous membrane irritation • Rapid loss of chlorine	• Urine-like odor • Increased cloudiness in the water • Pipes, pump impeller blades, and heater coils scaled with calcium • Calcium precipitates calcifying sand filters • Reduced effectiveness of chlorine

CHAPTER 6: CHLORINE

Chlorine is the most common disinfectant used in Pennsylvania aquatic facilities. Chlorine works well as a disinfectant if used properly. The following information will provide operators with the necessary understanding of chlorine disinfection that is critical to safely maintain an aquatic facility using chlorine.

Combined Chlorine (CC) = Total Chlorine (TC) - Free Chlorine (FC)

This formula is important because it is used to determine combined chlorine levels. Free and total chlorine levels are tested by using a test kit and must be tested to 0.1 ppm per state regulation.

Combined chlorine levels should never exceed 0.2 ppm. Combined chorine is responsible for poor air quality and reduced disinfectant strength. At high levels, combined chlorine and the resulting chloramines have hospitalized patrons at aquatic facilities. Long-term low-level exposure to chloramines is also responsible for the lung ailment known as “Lifeguard Lung.”

Combined chlorine levels are reduced by increasing the free chlorine level to ten times the combined chlorine level. This process is known as superchlorination and must be conducted during hours of closure. Ventilation in indoor environments is critical during superchlorination because chloramines will be burned off or volatilized and released into the atmosphere.

Free Chlorine

The residual free chlorine during open hours of operation should be kept at 2-4 ppm and never exceed 5 ppm. Free chlorine (FC) consists of hypochlorous acid (HOCl) and hypochlorite ions (OCl^-) which are in equilibrium. This is also written FC = HOCl + OCl^-. Hypochlorous acid is a strong bactericide and oxidizer, making it very useful in maintaining a clear and safe pool. HOCl is the key agent for killing microbial organisms and breaking down organic material from sweat, urine, and body oils.

The free chlorine equilibrium, however, shifts toward the less active hypochlorite ion as pH increases. The general reduction in hydrogen ion numbers found at a higher pH is known as the limiting factor for hypochlorous acid production. This is because hydrogen ions are necessary to form HOCl or hypochlorous acid. Thus, the higher the pH, the less hypochlorous acid is available to disinfect the water. This will result in an increased potential for outbreaks to occur and requires higher amounts of free chlorine to be added to provide a safe level of disinfection. Please keep in mind, free chlorine does not equal hypochlorous acid (HOCl). The critical relationship between pH and hypochlorous acid (active chlorine) is illustrated in Table 5, below.

Table 5: pH vs. Active & Inactive Chlorine

pH	Percentage HOCl (active chlorine)	Percentage OCl^- (inactive chlorine)
6.0	97	3
6.5	91	9
7.0	73	27
7.1	71	29
7.2	**66**	**34**
7.3	**60**	**40**
7.4	**56**	**44**
7.5	**50**	**50**
7.6	**45**	**55**
7.7	40	60
7.8	36	63
7.9	30	70
8.0	24	76
8.1	22	78
8.2	19	81
8.5	9	91
9.0	1	99

Pennsylvania regulations require that the pH never rise above 8.2. From this table, pH levels higher than 7.5 will result in less than half of the chlorine entering the water forming the more useful hypochlorous acid. At a pH of 7.2, approximately 66 percent of the chlorine dissolved in water will convert to hypochlorous acid, but at a pH of 8.2, only 19 percent of the dissolved chlorine forms hypochlorous acid.

Lower pH levels mean more of the chlorine added to the water is used for disinfection and more disinfectants per dollar spent on chlorine. It is therefore, more cost effective and protective to public health to keep the pH relatively low. **Thus, the recommended operational range for free chlorine is 2–4 ppm and pH is 7.2–7.6**. These ranges result in optimal bather comfort, disinfection, and hypochlorous acid production.

CHAPTER 7: SUPPLEMENTAL DISINFECTION

Ozone and Ultraviolet Light Chambers are good supplemental disinfection systems because if used properly, they will inactivate pathogens. Please keep in mind, ozone can be hazardous by degrading air quality, and it is a greenhouse gas. Manufacturer instructions must be closely followed when using ozone. Also, the effectiveness of Ultraviolet Light Chambers is reduced by turbidity (cloudiness), life of bulb, and dissolved metals. Excellent water quality is critical to the effectiveness of Ultraviolet Light Chambers (UV). UV does, however, have the additional benefit of burning off combined chlorine as well as enhancing disinfection and air quality.

These supplemental disinfection systems do add another layer of protection and disinfection, but they cannot stand alone because they do not create a residual that remains in the water. Thus, supplemental disinfection must be accompanied by chlorine or other approved disinfectants.

CHAPTER 8: INDOOR AIR QUALITY

Indoor air quality and human health can be significantly degraded as the result of poor aquatic facility operations. Good, indoor air quality can be maintained by controlling water chemistry, humidity, air and water temperature, air changes, and combined chlorine and chloramines. Per ASHRAE standard 1999b, it is recommended that relative humidity should be kept at 50-60 percent. The most effective way to achieve this humidity range is to maintain the air temperature at 2-5 degrees above the water temperature. Reductions in chloramines and humidity are also achieved by providing the recommended six air changes per hour to introduce plenty of fresh air. Finally, to control chloramines, the level of combined chlorine should never be above 0.2 ppm.

CHAPTER 9: FILTRATION & FLOCCULATION

The primary function of filtration is to remove particles from the water. The type of filter and filter media used determines the size of the particles that can be filtered from aquatic facility water. Filterable particle sizes range from greater than 25 microns (µ) for sand filters to greater than 4 microns for diatomaceous earth (DE) filters. Sand filtration is the most common type of filtration used at aquatic facilities and is not capable of removing chlorine resistant Cryptosporidia oocysts because they are 4-6 microns in diameter. Flocculants such as aluminum sulfate (alum) will cause microscopic particles including oocysts to stick together and become trapped in a sand filter. Thus, the regular use of flocculants and the addition of flocculation during enhanced Cryptosporidia treatment will add another layer of protection against microbial pathogens by removing them from pool water. This is important for pools using cyanuric acid because cyanuric acid may render disinfectants powerless against Cryptosporidia. Follow manufacturer guidelines when using flocculants.

Filtration and disinfection become meaningless unless proper turnover rates are maintained. Turnover rates are a measure of the time it takes to filter and disinfect the entire body of water. Keep in mind that the entire body of water is constantly diluting and mixing. This mixing results in fractional filtration of the water with nearly four turnovers, one every six hours, being necessary to filter almost all the water of a pool. Turnover rates differ depending on the type of unit being filtered. Because most of the water of an aquatic facility is not constantly in contact with the filter, it becomes critical to operate at the recommended ranges of water chemistry parameters outlined in Table 1 to eliminate pathogens.

CHAPTER 10: CYANURIC ACID (stabilizer)

The use of cyanuric acid (stabilizer) is not recommended in Pennsylvania public aquatic facilities. Cyanuric acid forms a weak bond with chlorine and provides chlorine with protection against burn off from the sun's rays, but cyanuric acid can negatively affect human health and reduces the effectiveness of disinfectants. When treating for Cryptosporidia contamination at aquatic facilities, cyanuric acid may render disinfectants, including doses of 40 ppm residual chlorine, useless.

Disinfectants such as Trichlor (Trichloro-S-Triazinetrione) and Dichlor (Dichloro-S-Triazinetrione) continually add chlorine and cyanuric acid to pool water. As the chlorine burns off, the cyanuric acid stays and increases over time. This increase in cyanuric acid has an inverse relationship with chlorine strength. Thus, the chlorine is weakest at the end of the summer swimming season in pools using trichlor and dichlor because that is when cyanuric acid levels are highest in these pools. This is also when most of the outbreaks of cryptosporidiosis occur. Due to this correlation, the use of trichlor and dichlor is not recommended**.**

If cyanuric acid is used however, it should be added only once at the beginning of the swimming season at levels less than 20 ppm. Cyanuric acid should never be used in indoor units or in any type of outdoor unit other than a pool. A disinfectant other than one containing cyanuric acid should be used continually throughout the swimming season so that the cyanuric acid level is not increased. It is also recommended that supplemental disinfection, UV or ozone, and flocculants be used as added protection against pathogens in pools using cyanuric acid.