SWIMMING POOL WATER QUALITY STANDARD AND MONITORING GUIDELINES

FOR PUBLIC POOL OPERATORS

Environment Control Section
Engineering Services Division
Ministry of Health, Malaysia

JUNE 2017

SWIMMING POOL WATER QUALITY STANDARD AND MONITORING GUIDELINES
(For Public Pool Operators)

Pengesahan Ketua Pengarah Kesihatan

Adalah dengan ini saya *mengesahkan / ~~tidak mengesahkan~~ ***SWIMMING POOL WATER QUALITY STANDARD AND MONITORING GUIDELINES (For Public Pool Operators)*** untuk tujuan rujukan dan kegunaan semua anggota Kementerian Kesihatan Malaysia, badan regulatori dan juga edaran bagi pelaksanaannya oleh pihak-pihak yang berkenaan.

DATUK DR SHAHNAZ MURAD
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Tarikh: 25.8.17

* Potong yang mana tidak berkaitan

FOREWORD BY THE DIRECTOR GENERAL OF HEALTH MALAYSIA

This Standard and Guidelines is developed by the Ministry of Health as a practical guide to assist and create awareness among pool operators in managing their pool water quality. They are responsible for ensuring that their pools are well maintained and operated within the specified standard. This precaution in a way will help control and prevent the occurrence of water borne diseases due to microbial contaminants in the pool water.

Various international standards and guidance documents, especially those published by the World Health Organization (WHO) have been referred in developing this Standard and Guidelines.

In addition, the Ministry of Health collaborates with the Ministry of Urban Wellbeing, Housing and Local Government towards incorporating the requirement of swimming pool water quality in its relevant guidelines.

For the enhancement of public health, the Ministry of Health will continue to monitor the quality of the pool water at regular intervals for public pools throughout the country in ensuring the wellbeing of visitors and users of pools.

My congratulation to the team for their joint-effort in developing this Standard and Guidelines. I would also like to convey my gratitude to the Kuala Lumpur City Hall and Ministry of Urban Wellbeing, Housing and Local Government for their assistance and technical input.

Datuk Dr. Noor Hisham bin Abdullah
Director General of Health Malaysia

FOREWORD BY THE DIRECTOR OF ENGINEERING SERVICES DIVISION

In recent years there has been a rise in the number of cases of people getting ill after bathing in public swimming pools. The illnesses are mainly due to water borne infectious diseases brought about by pathogenic micro-organisms that had found their way into the pool water. All these pathogens are brought into the pool by the people using the pools and the surrounding environment. Even though the water used in swimming pools comes directly from the public water supply and have already been treated, the need to undergo further and continuous treatment is necessary to ensure the water is free from any pollutants and safe for its users. In order to provide safe and clean pool water, the treatment system of pools need to be given emphasis by pool operators in terms of management, operation and maintenance.

This Standard and Guidelines is intended mainly as a practical guide to assist public pool operators in their day to day operation of their pools and spas. It is developed by the Ministry of Health and related agencies by making references to various international standards and guidance documents, especially those published by the World Health Organization (WHO). The Ministry of Health is collaborating with the Ministry of Urban Wellbeing, Housing and Local Government to ensure the pool water quality operated by pool operators throughout the country meet the required standard.

This pool water quality standard will enable pool operators to carry out self-monitoring and the guidelines will assist them to identify the weaknesses in their pool treatment systems as well as the possible causes. Recommendations for remedial actions are also proposed as a guide for pool operators to rectify the weaknesses. With this Standard and Guidelines, it is hope that pool operators could give due diligence in operating, maintaining and improving their pool treatment systems. Their good effort would play a major role in safe-guarding the health and safety of bathers.

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1.0 INTRODUCTION

The primary objective of monitoring the water quality of swimming pool is to ensure that the water that comes into contact with bathers is in a safe and pleasant condition. Thus, a good monitoring regime can help to prevent infections by microbial contaminants, ensure that the water is aesthetically acceptable, and prevent adverse health effects or significant discomfort to pool users that may be caused by the presence of chemical constituents or poor physical characteristics of the water. As such, focus should be directed towards effective and efficient treatment of the pool water.

Public swimming pool users are susceptible to infection by a diversity of disease-causing organisms. Bathers in public swimming pools are more likely to be exposed to disease-causing organisms compared to bathers in domestic or private pools because public pools are subjected to contamination via a wider community. Disease-causing organisms may be introduced from many sources but are mainly associated with bathers. These organisms may be brought into a pool from the bathers' skin, their saliva, urine and unintentional faecal discharge. These organisms may also be introduced from dust, bird's droppings, make-up water as well as soil carried on bathers' feet. Some of these disease-causing organisms live and may even grow in pool water unless the pool water is disinfected effectively and efficiently in a continuous manner.

Tintometer GmBH Lovibond (2016), summarises the objective of pool water treatment specifically to:

1.1 keep the water free of pathogenic (harmful) bacteria;

1.2 keep the water free from growths of algae;

1.3 ensure the water is neither toxic nor irritating to swimmers;

1.4 prevent the formation of undesirable smells or taste in the water;

1.5 prevent corrosion of the pool surroundings, its fittings and equipment; and

1.6 prevent scale formation in the pool, filter or pipework.

Swimming pools present no infection risks if their treatment systems are managed properly. Regular testing of pool water is, however, essential to ensure effective water treatment and is the only satisfactory way of determining rapidly whether disinfection is adequate and the water is balanced.

This guidelines provides the water quality standard for microbiological, chemical and physical parameters that a swimming pool should meet. It must be emphasized that proper design, construction, maintenance and operation of a pool, in accordance to accepted standard, are critical towards achieving a pool that does not pose any health risks to users. Therefore, on no account, shall the testing of pool water, however regular and exhaustive, and whatever their analytical results may be, be used to condone improper design, construction, maintenance and/or operation.

2.0 PURPOSE

The purpose of this Standard and Guidelines is to assist pool operators to manage their pools with respect to treatment systems so that the pool water is of adequate quality that will eventually reduce risks to users in terms of health and safety. Hence, pool operators shall be responsible for ensuring that their pools are well maintained and operated within the specified standard.

3.0 DEFINITIONS

A list of definitions of various terminologies used in this Standard and Guidelines are as shown in **Table 1**.

Table 1: Definitions

Standard and Guidelines	Swimming Pool Water Quality Standard and Monitoring Guidelines for Public Pool Operators.
Public swimming pool	Swimming pool operated by agencies and companies (Local Authorities, Ministry of Youth and Sports, institutions, hotels, resorts, clubs, etc.) that are accessible by public with or without entrance fee.
Private swimming pool	Any swimming pool other than public swimming pool constructed and used for swimming or recreational bathing, that is intended to be used by individual, family members and close relatives only.
Pool operator	An individual or an organization that owns and/or manages the daily operation of its swimming pool or pools.
Disinfection	To free the swimming pool water from pathogens (disease carrying microorganisms).
Disinfectants	A compound or substance which, when applied as instructed to swimming pool water, may kill micro-organisms.
Chlorine (Cl_2)	A halogen with disinfecting properties that is converted to hypochlorous acid in water (HOCl.)
Filling water	The water used for initial filling and for make-up.
Bathing load	A measure of the number of people in the pool.

Total Dissolved Solids	Sum of concentrations of dissolved compounds, e.g. hardness salts, treatment chemicals, etc. that are present in the water.
Free residual chlorine	Residues of hypochlorous acid/hypochlorite ion (irrespective of the mode of addition or formation) that remains in the water at a specific point of time after a certain amount of hypochlorous acid/hypochlorite ion that had been added to the water has undergone the disinfection process.
Combined residual chlorine	The product of reaction when free chlorine (hypochlorous acid) comes into contact with ammonia (from urine) in the water, whereby chloramines are formed.
Total residual chlorine	The sum of concentrations of combined residual chlorine and free residual chlorine.
pH	A scale (ranging from 0 to 14) that indicates the acidic or alkaline level of the water. Water with a pH of 7 is neutral.
Hydrotherapy or therapeutic pool	A pool containing heated water and specially designed to meet the therapeutic needs of persons of any age with impairments due to illness, injury, disease, intellectual handicap or congenital defects or for fitness exercising.
Cyanuric acid	A chemical added to chlorine as a stabilizer to reduce chlorine loss due to the action of ultra violet rays from the sun for outdoor pools.

4.0 SCOPE

This standard and guidelines applies to swimming pools that are opened to the public and include pools at the following premises:

4.1 Municipal and commercial sites;

4.2 Schools;

4.3 Hotels and motels;

4.4 Leisure centres, clubs and resorts;

4.5 Camps;

4.6 Recreational water parks (wave pools, wading and receiving pools, etc.);

4.7 Spa and gymnasiums; and

4.8 Apartments, condominiums and private pools.

However, private pool operators may use this standard and guidelines for reference to ensure safe use of pool waters by bathers.

This standard and guidelines shall not apply to the following:

4.1 Natural water bodies; and

4.2 Hydrotherapy and therapeutic exercise pools.

5.0 PARAMETERS TO BE MONITORED

The parameters of interest that should be monitored regularly are listed in **Table 2**.

Table 2: Parameters monitor

Parameters	Justification
Physical	
i. pH	• Correct pH range necessary to ensure efficient disinfection and coagulation. • To avoid damage to the pool fabric *(corrosion)* and ensure user comfort *(prevent eyes and skin irritation)*.
ii. Turbidity	Exceedance of turbidity indicates: • significant deterioration in water quality; • significant health hazard; and • reduce aesthetic value. • May increase the amount of disinfectant use.
iii. Temperature	Plays an important role in maintaining comfort of bathers, pH control, growth rate of microbiological organisms and disinfectant concentrations. • Warmer temperatures favour bacterial growth such as *Legionella* in filter media, which may be transmitted by aerosols in pool. At temperatures exceeding 26°C, growth and survival of *Pseudomonas aeruginosa* is enhanced. • Water ranging in temperature from 26 to 30 °C is comfortable for most swimmers throughout prolonged periods of moderate physical exertion.

Chemical		
iv.	Free Residual Chlorine	To ensure efficient disinfection
a.	Combine Residual Chlorine (Chloramines)	If the level exceeds 50% of free chlorine concentration, it may indicate that: • bathing loads or pollution from bathers are too high; • dilution is too low or that treatment is suboptimal. • Combined Residual Chlorine = Total Residual Chlorine – Free Residual Chlorine
i.	Total Alkalinity	• Alkalinity is a measure of the buffering capacity of water or the capacity of bases to neutralize acids. Refers to the ability of water to resist change in pH. • Primarily the bases bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) are the main contributors (dissolved alkaline salts). • Cyanuric acid which is used as chlorine stabilizer for outdoor pools also contributes to the alkalinity (approximately equivalent to $^1/_3$ of the cyanuric acid content in the water) apart from the bicarbonate and carbonate bases and hence, Total Alkalinity is monitored. • Total Alkalinity is expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate).
ii.	Hardness	• To avoid damage to the pool fabric (e.g. etching of surfaces and metal corrosion) • To prevent scaling water.
iii.	Total Dissolved Solids	• High level indicates overloading of dissolved salts or lack of dilution.
iv.	Cyanuric Acid	• Stabilizing agent to reduce the rate of dissipation of chlorine due to the effect of the sun's ultraviolet rays. • High levels reduce efficiency of disinfection, i.e. require longer time to disinfect bacteria. • High levels of cyanuric acid cause a situation known as 'chlorine lock', when even very high levels of chlorine become totally locked with the cyanuric acid (stabilizer) and unavailable as disinfectant. • High levels make water looks dull and lifeless and perhaps have a greenish tint.

v.	Nitrate	• Nutrients that promote algae growth, which is a nuisance to swimming pools. • Increases the amount of chlorine use.

Microbiology		
i.	Escherichia *coli* (*E. coli*)	• An indicator for faecal contamination. • Faecal contamination means there is a risk of other disease causing micro-organisms (pathogens) present in the water that may cause acute health problems when ingested.

6.0 WATER QUALITY STANDARD

The acceptable standard values for parameters to be monitored are listed in **Table 3.** These standard values are applicable to treated pool waters. Particular attention shall be given to parameters that have direct or close association with the disinfection process.

Table 3: Water Quality Standard for Swimming Pools

No.	Parameters	Unit	Standard Values
1	Free residual chlorine	mg/l	0.5 – 3.0
2	pH	-	7.0 – 7.8
3	Turbidity	NTU	≤ 5.0
4	Temperature	°C	21.2 – 32.2
5	Total Alkalinity (as $CaCO_3$)	mg/l	80 – 200
6	Hardness (as $CaCO_3$)	mg/l	75 – 250
7	Total Dissolved Solids	mg/l	≤ 1000
8	Cyanuric acid	mg/l	≤ 50
9	Nitrate (as NO_3 - N)	mg/l	≤ 10
10	Escherichia coli (*E. coli*)		Absent in 100 ml

Filling water quality should meet potable water quality standards, i.e. the National Drinking Water Quality Standards established by the Ministry of Health, Malaysia.

7.0 CIRCULATION AND HYDRAULICS (TURNOVER PERIOD)

Circulation and hydraulics is to ensure that the whole pool is adequately served by filtered, disinfected water. Treated water must get to all parts of the pool, and polluted water must be removed – especially from areas most used and most polluted by bathers. Without good circulation and hydraulics, even water treatment may not give adequate pool water quality.

The circulation rate is defined as the flow of water to and from the pool through all the pipework and the treatment system. The appropriate circulation rate depends, in most cases, on bathing load but not all types of pool can realistically be derived from bathing load, such as diving pools and other waters more than 2 m deep, where the bathing load relative to water volume may be very low.

Circulation rate is related to turnover period, which is the time taken for a volume of water equivalent to the entire pool water volume to pass through the filters and treatment plant and back to the pool.

The turnover period can be calculated as follows.

$$\text{Turnover in hours} = \frac{\text{Pool capacity } (m^3)}{\text{Filter rate } (m^3/hr)}$$

The suitable turnover period is dependent on the particular type of pools as the likely pollution load of these pools are based on the type of activity undertaken and the volume of water within the pool. As a general guide the British Standard Institution (BSI) Code of Practice in Swimming Pool, 2003 is used and it is as shown in **Table 4**.

Table 4: Recommended turnover period according to pool types

Pool Type	Turnover Period
Competition pools 50 m long	3 – 4 h
Conventional pools up to 25 m long with 1-m shallow end	2.5 – 3 h
Diving pools	4 – 8 h
Leisure water bubble pools	5 – 20 min
Leisure waters up to 0.5 m deep	10 – 45 min
Leisure waters 0.5–1 m deep	0.5 – 1.25 h
Leisure waters 1–1.5 m deep	1 – 2 h
Leisure waters over 1.5 m deep	2 – 2.5 h
Teaching/learner/training pools	0.5 – 1.5 h
Water slide splash pools	0.5 – 1 h
Hydrotherapy pools	0.5 – 1 h

8.0 CAPACITY AND BATHING LOAD

For safety purpose, pool operators are recommended to ensure that the number of pool users do not exceed the allowable maximum limit at any one time. Maximum allowable limit can be determined based on the depth of swimming pools. The maximum bathing load can be determined based on the British Standard Institution (BSI) Code of Practice in swimming pool, 2003 as shown in **Table 5**.

Table 5: Maximum allowable bathing load for swimming pool (BSI Code of Practice in Swimming Pools, 2003).

Water Depth	m^2 per person
< 1m	2.2
1m – 1.5m	2.7
> 1.5m	4

9.0 DILUTION WITH FRESH WATER

Coagulation, filtration and disinfection will not remove all pollutants. Swimming pools should be designed to enable the dilution of pool water with fresh water. Dilution limits the build-up of pollutants from bathers (e.g. constituents of sweat and urine), of by-products of disinfection and of various other dissolved chemicals. Dilution rates need to account for the replacement of water used in filter backwashing, evaporation and splash-out. As a general rule, the addition of fresh water to disinfected pools should not be less than 30 litres per bather.

10.0 SAMPLING AND TESTING FREQUENCY

It is good practice and highly recommended for pool operators to carry out routine tests as a means of self-checking or self-monitoring to ensure their pool waters are safe to use. The parameters and their corresponding test frequencies are described in the following sub-sections.

10.1 Daily on-site testing

For pools **without** automatic continuous monitoring and control equipment, **temperature, pH and free residual chlorine** levels shall be monitored daily. Daily monitoring shall be carried out prior to opening and with a minimum of one test per sampling point for each pool (if more than one pool) and for each session of pool operation (ideally during periods of high bathing load). However, the number of sampling and testing per sampling point shall not be less than three per day.

For pools **with** automatic continuous monitoring and control equipment, manual testing of **temperature, pH and free residual chlorine** shall be carried out daily with a minimum of one test for each pool (if more than one pool) and for each session of pool operation (ideally during periods of high bathing load). However, the number of manual sampling and testing shall not be less than two per day. The readings of automatic continuous monitoring shall be checked against the corresponding manual test results. As the difference between manual pool test results and the continuous measurement readings will vary, it is the consistency of variation that is paramount. Diverging or converging readings should be

investigated. All automatic monitoring devices shall be calibrated and maintained according to the manufacturer's instructions.

10.2 Monthly examination for E. coli, turbidity, nitrate and cyanuric acid

Pool operators shall arrange for the collection and transportation of water samples to the any accredited laboratories for analysis of E. coli at least once a month for verification of the treatment system. Turbidity, nitrate and cyanuric acid shall also be tested at least once a month.

As for other parameters that are tested on daily basis, it is good practice to carry out those tests at the same time of taking samples for E.coli examination.

10.3 Quarterly testing for chemical parameters

Apart from free residual chlorine which is tested on a daily basis as well as nitrate and cyanuric acid which are tested on a monthly basis, all other chemical parameters such as total alkalinity, hardness and total dissolve solids shall be tested at least once every three months. It is good practice to test all parameters (physical, chemical, E.coli) at the same time during quarterly testing.

10.4 Monitoring E. coli, free residual chlorine, pH and temperature under special conditions

10.5 Examination of E. coli and testing of free residual chlorine and pH shall also be carried out under special circumstances, such as:

a) Before a pool is opened for the first time.
b) Before a pool that has been shut down for repairs or cleaning is put back into use.
c) When there are anomalies or difficulties with the treatment system.
d) As part of any investigation into possible adverse effects on bathers' health.

Examination of E. coli and testing of free residual chlorine and pH shall continue for at least once a week for the first two months of pool operation for conditions (a) to (d). After the first two months, monitoring should continue as normal as in subsection 8.2. Examination should ideally be carried out during period of high bathing load.

10.6 Surveillance by authorities

Ministry of Health or any relevant enforcement authorities shall reserve the right to take or direct the pool operator to take samples for examination of water quality, as and when required.

10.7 Additional requirements and conditions by local authorities

Notwithstanding subsections 8.1, 8.2, 8.3, 8.4 and 8.5, pool operators shall abide by all requirements and conditions set forth in any enactments or regulations enforced by the respective local authorities.

11.0 TEST PROCEDURES

11.1 For E. coli examination, all samples shall be analysed by an accredited laboratory. The sampling bottle must be sterile and contain an agent that neutralizes the disinfectant used in the pool water. Sodium thiosulfate (18–20 mg/l) is the agent used for chlorine-based and bromine-based disinfectants. Nevertheless, the testing laboratory must be advised before sampling if any other disinfectant is being used.

11.2 For testing of physical and chemical parameters, tests can be carried out by using on-site testing instrument or test kits.

11.3 If so required pool operators may also arrange for the collection and transportation of water samples to any accredited laboratories for analysis of chemical parameters.

11.4 Pool operators shall adhere to current procedures recommended by the accredited laboratory with regards to sample containers, preservatives, storage and transport.

12.0 SAMPLING LOCATIONS

12.1 Samples of pool water should be taken at a location furthest away from the inlet or from the point of disinfectant dosing whereby the flow velocity and disinfectant residual is generally lowest. Depending on the hydraulics of the pool system, the lowest flow velocity and lowest disinfectant residual level will normally occur near the water outlet, e.g. the skimmer box or scum gutter.

12.2 Samples should be taken at a depth of 50 - 300 mm and at a minimum distance of 500 mm from the edge of the pool.

12.3 Samples for regular monitoring should be taken at the same location.

12.4 All samples shall be taken during period of high bathing load.

12.5 Sampling at multiple locations is necessary to determine the area of lowest reading. As a general guide the number of sampling locations are determined by using **Table 6**.

Table 6: Number of sampling locations

Surface Area of Pool (m2)	Number of Sampling Locations
< 400	1
≥ 400 and < 800	2
≥ 800 and < 1200	3
≥ 1200	4

13.0 OPERATIONAL ISSUES AND REMEDIAL ACTIONS

13.1 Remedial actions for accidental release of faeces or vomit into pools.

Accidental faecal releases into swimming pools and similar environments can lead to outbreaks of infections associated with faecal-derived viruses, bacteria and pathogenic protozoa. Vomit may also have similar effects. When faced with an accidental faecal release or vomit in the pool water a pool operator must act immediately.

If the faecal release is a solid stool, it should simply be retrieved quickly and discarded appropriately. The scoop used to retrieve it should be disinfected so that any bacteria and viruses adhering to it are inactivated and will not be returned to the pool the next time the scoop is used. As long as the pool is operating properly (i.e. disinfectant levels are maintained), no further action is necessary. The same applies to solid animal faeces.

If the stool is runny (diarrhoea) or if there is vomit, the situation is more likely to be hazardous, as the faeces or vomit is more likely to contain pathogens. Even though most disinfectants deal relatively well with many bacterial and viral agents in accidental faecal releases and vomit, the possibility exists that the diarrhoea or vomit is from someone infected with one of the protozoan parasites, Cryptosporidium and Giardia. The infectious stages (oocysts/cysts) are resistant to chlorine disinfectants in the concentrations that are practical to use. The pool should therefore be cleared of bathers immediately.

The safest action, if the incident has occurred in a small pool, is to empty and clean it before refilling and reopening. However, this is practically impossible in many larger pools, for reasons of cost and extended periods of closure. If draining down is not possible, then a procedure based on the one given below should be followed (it should be noted, however, that this is an imperfect solution that will only reduce but not eliminate risk):

- The pool should be cleared of people immediately.
- As much of the material as possible should be collected, removed and disposed of to waste; this may be done through netting, sweeping and/or vacuuming (provided the equipment can be adequately disinfected after use).
- Disinfectant levels should be maintained at the top of the recommended range or super-chlorination to 20 mg/l at pH 7.2 – 7.5 and holding for 8 h (shock dosing) should be performed.
- Using a coagulant (if appropriate), the water should be filtered for six turnover cycles; this may mean closing the pool until the next day.
- The filter should be backwashed (and the water run to waste).
- The final residual disinfectant level and pH value should be checked, and if satisfactory, then the pool can be reopened.

13.2 Other operational problems, possible causes and proposed remedial actions.

Table 7 is provided as a general guide for pool operators to take remedial actions on some possible problems that may occurred during the operation of the pool.

Table 7: Operational problems, possible causes and proposed remedial actions for pool operators

Problems	Possible cause	Proposed remedial action
E. coli detected	Inadequate disinfectant level or no measurable free disinfectant residual	Check to ensure free disinfectant residual level is adequate throughout the pool.
Pool water going green due to presence of algae	No stabilizer in pool – sunlight dissipating disinfectant	Check disinfectant level and add stabilizer if necessary. or Use disinfectant with stabilizer (cyanuric acid for chlorine disinfectant) such as sodium di-chloroisocyanurate (dichlor) or tri-chloroisocyanuric acid (trichlor)
	High cyanuric acid level (150 – 200 mg/l) causes chlorine lock	Dilute with fresh water to reduce cyanuric acid to standard value. And if necessary, shock-dose with 10 mg/l of either Sodium or Calcium Hypochlorite and hold for 4 hours to kill any algae growth.
Algal growth on walls and base of pool	Inadequate disinfectant level	Check to ensure disinfectant level is adequate throughout the pool and use algicide. And if necessary, shock-dose with 10 mg/l of either Sodium or Calcium Hypochlorite and hold for 4 hours to kill any algae growth.
Water looks dull and lifeless	Total dissolve solids (TDS) too high	Check and reduce TDS by dilution.
	High cyanuric acid level (150 – 200 mg/l) causes chlorine lock	Check and reduce cyanuric acid by dilution.

Problems	Possible cause	Proposed remedial action
Salty taste in water	Total dissolve solids (TDS) too high	Check and reduce by dilution.
	High chloride level	
Cloudy water	Heavy bather load over-loading the filtration system	Reduce bather load and check filters.
	High pH	Check and adjust pH.
	High alkalinity	Check and adjust alkalinity.
Signs of erosion of cement grout between tiles	Hardness too low (Soft water) – Calcium demand	Check and adjust hardness.
	pH too low	Check and adjust pH.
	High sulphate level	Check and reduce to 360 mg/l if necessary.
pH erratic (fluctuates easily)	Low alkalinity	Check and adjust alkalinity.
pH difficult to adjust	High alkalinity	Check and reduce alkalinity if necessary.
Complaints of smarting eyes and skin irritation	pH outside recommended range	Check and adjust pH.
	Combined residual chlorine level > 50% of free chlorine level due to too much ammonia in the water	Check and adjust chlorine dose. Normally dilution by fresh water is necessary.

13.3 pH adjustment

The chemical required for pH adjustment will generally depend on whether the disinfectant used is itself alkaline or acidic. Alkaline disinfectants (e.g. sodium hypochlorite) normally require only the addition of an acid for pH correction, usually a solution of sodium hydrogen sulphate, carbon dioxide or hydrochloric acid. Acidic disinfectants (e.g. chlorine gas) normally require the addition of an alkali, usually a solution of sodium carbonate (soda ash).

13.3.1. To raise the pH level the following chemicals can be added:

- Sodium Carbonate (Na_2CO_3) or Soda Ash. This has a pH value of around 10 and will also raise the alkalinity of the water. Caution: Do not add more than 460 g of soda ash per 38,000 litres of water at a time as it may cause the pool to cloud ("milky" consistency). Also, if the alkalinity is over 120 mg/l, the addition of soda ash may also cause your water to cloud. Refer to the chart in **Appendix 1** for estimating the amount of sodium carbonate to be added to raise the pH to the ideal level.

- Sodium Hydroxide (NaOH) or Caustic Soda – very alkaline with a pH of 14 and must be handled with care. This will also raise the alkalinity of the water.

13.3.2. To lower the pH level the following chemicals can be added:

- Sodium Hydrogen Sulphate ($NaHSO_4$), Sodium Bisulphate or Dry Acid – a free flowing crystalline powder or granules which in solution has a pH of 1. Normally dissolved in some water in a plastic container and then sprinkled around the pool. It also adds sulphate to the water. Refer to the chart in **Appendix 2** for estimating the amount of sodium bisulphate to be added to lower the pH to the ideal level.

- Hydrochloric Acid (HCl) also known as Muriatic Acid – an economical pH reducer but handling can be a problem. The concentrated acid (32%) is highly corrosive. Commercial grades should not be used as their iron content may be high and this could cause discolouration and cloudiness in the water. It is advisable to dilute the concentrated acid by adding to water in a plastic container before sprinkling it around the pool. (**NOTE Always add acid to water, not the other way around**). Refer to the chart in **Appendix 3** for estimating the amount of hydrochloric acid to be added to lower the pH to the ideal level.

13.4 Alkalinity adjustment

Alkalinity is a measure of the alkaline salts (carbonates, bicarbonates and hydroxides) dissolved in the water. The higher the alkalinity, the more resistant the water is to large changes in pH in response to changes in the dosage of disinfectant and pH correction chemicals. If the alkalinity is too high, it can make pH adjustment difficult. An optimum level of alkalinity is required for a pool – usually around 100 mg/l measured as calcium carbonate $CaCO_3$. Alkalinity at levels below 50 mg/l may cause "pH bounce" which means large changes in pH value in response to changes in dosing levels of disinfectant and/or pH correction chemicals. If, however the alkalinity rises to over 200 mg/l it can make any pH adjustment difficult, and cause cloudiness in the water.

The recommended level of total alkalinity in a pool should be based on the type of disinfectant in use:

a)	Chlorine gas	:	180 – 200 mg/l
b)	Sodium hypochlorite	:	120 – 150 mg/l
c)	Calcium hypochlorite	:	80 – 120 mg/l
d)	Dichlor and Trichlor	:	100 – 120 mg/l

13.4.1. To raise alkalinity level:

- Refer to the chart in **Appendix 4** for estimating the amount of sodium bicarbonate to be added to raise the level of alkalinity.

13.4.2. To lower alkalinity level:

- Refer to the chart in **Appendix 5** for estimating the amount of sodium bisulphate to be added to reduce the level of alkalinity.

- Refer to the chart in **Appendix 6** for estimating the amount of hydrochloric acid 32% to be added to reduce the level of alkalinity.

13.5 Hardness adjustment

If the calcium hardness in a pool is below 70 mg/l as $CaCO_3$ the water is soft and likely to become corrosive to the pool structure. Soft water will cause problems in pools as it has a "calcium demand" and seek out calcium from the pool structure (tile grouting and painted concrete surface) leaving gaps between tiles and ultimately the tiles become dislodged due to erosion of the cement. Hardness level could be raised by the addition of calcium chloride flake. Calcium chloride flake is very soluble and will add chloride ions to the water, thereby increasing the total dissolved solids content. Refer to the chart in **Appendix 7** for estimating the amount of calcium chloride to be added to raise the level of hardness.

High levels of calcium hardness can be lowered by replacing some of the pool water with fresh water containing lower natural hardness.

13.6 Cyanuric acid (chlorine stabilizer) adjustment

Cyanuric acid is a chemical added to the pool water to protect free chlorine from the degrading effects of the sun's ultraviolet (UV) rays. If the chlorine used is dichlor or trichlor, no additional dosing of cyanuric acid is necessary since it is already a part of these disinfectants. For effective chlorine stabilization, the recommended minimum cyanuric acid concentration is 10 mg/l, and the ideal range is 30-50 mg/l. Chlorine lock usually occurs at levels between 150 – 200 mg/l. Refer to the chart in **Appendix 8** for establishing or increasing the amount of cyanuric acid to the required level.

To reduce the concentration of cyanuric acid to the standard value, the most common way is to drain part or all of the water and refill. Draining and replacing half the water will result in a 50% reduction of the cyanuric acid concentration.

13.7 Shock-dose chlorine

The simple equations for estimating the amount (in terms of weight) of chlorine compound to be used for shock-dosing a pool water is as follows:

$D = R_{sd} - R_e$ (Eqn. 1)

$K = \frac{VD}{10S}$ (Eqn. 2)

Where,

K	=	Amount of chlorine compound (grams) needed to treat the pool water
V	=	Volume of pool water to be shock-dosed (litres)
D	=	Chlorine dose (mg/l)
S	=	Available chlorine in chlorine compound (%)
R_{sd}	=	Required free residual chlorine after shock-dose
R_e	=	Existing free residual chlorine in the pool water

14.0 RECORDS

14.1 Daily log as in subsection 10.1

A daily log shall be kept in a systematic and tidy manner by pool operators and the information to be recorded in the log is as follows:

- Date and time of testing
- Sample location
- Free residual chlorine level or any other residual disinfectant level (mg/l)
- pH
- Temperature (°C)
- Bathing load

14.2 Monthly monitoring records of E.coli and turbidity as in subsection 10.2

A monthly record for routine E.coli and turbidity monitoring shall be kept in a systematic and tidy manner by pool operators and the information to be recorded in the log is as follows:

- Date and time of testing
- Sample location
- E.coli detection (in units of cfu/100ml or MPN/100ml or absent/present)
- Turbidity (NTU)
- Cyanuric acid
- Nitrate
- Free residual chlorine level or any other residual disinfectant level
- pH
- Temperature (°C)
- Bathing load

14.3 Records of monitoring of E. coli, free residual chlorine, pH and temperature under special conditions as in subsection 10.4.

Records of monitoring of E. coli, free residual chlorine, pH and temperature that are conducted at least once a week for the first two months of pool operation shall be kept in a systematic and tidy manner by pool operators and the information to be recorded in the log is as follows:

- Date and time of testing
- Sample location
- E.coli detection (in units of cfu/100ml or MPN/100ml or absent/present)
- Free residual chlorine level or any other residual disinfectant level
- pH
- Temperature (°C)
- Bathing load

14.4 Quarterly monitoring records of chemical parameters as in subsection 10.3.

A quarterly record for routine monitoring of chemical parameters shall be kept in a systematic and tidy manner by pool operators and the information to be recorded in the log is as follows:

- Date and time of testing
- Sample location
- Total alkalinity
- Hardness
- Total dissolve solids
- Cyanuric acid
- Nitrate
- E.coli detection (in units of cfu/100ml or MPN/100ml or absent/present)
- Free residual chlorine level or any other residual disinfectant level
- pH
- Turbidity
- Temperature (°C)
- Bathing load

14.5 All records shall be kept for at least 12 months and be readily available for inspection by the Health Authorities or Local Authorities at all times.

15.0 OTHER GOOD PRACTICES

15.1 Pre-swim hygiene

- Pool operator has to ensure that bathers take a shower before entering the swimming pool. Showering will help to remove traces of sweat, urine, faecal matter, cosmetics, suntan oil and other potential water contaminants. Where pool users normally shower before swimming, pool water is cleaner, easier to disinfect with smaller amounts of chemicals and thus more pleasant to swim in. Shower water must run to waste.

15.2 Practical actions by pool operators to prevent accidental faecal release into pools

- No child (or adult) with a recent history of diarrhoea should swim.
- Parents should be encouraged to make sure their children use the toilet before they swim, and babies and toddlers that have not been toilet trained should ideally wear waterproof nappies or specially designed bathing wear.
- Young children should whenever possible be confined to pools small enough to drain in the event of an accidental release of faeces or vomit.
- Lifeguards should be made responsible for looking out for and acting on accidental faecal release/vomit incidents.

16.0 DUTIES AND RESPONSIBILITIES OF POOL OPERATORS

16.1 Pool operators shall be responsible for ensuring that their pools are maintained within the specified water quality standard. Immediate steps shall be taken to rectify any deviation from the standard.

16.2 Pool operators shall maintain and keep clean all test equipment, and shall subject test reagent to regular quality control.

16.3 Pool operators must be well trained to carry out the necessary tests and adhere to procedures for collection, storage and transportation of samples to the accredited laboratory.

16.4 For storage and handling of bulk chemicals, the pool operators shall refer to the Peraturan-Peraturan Keselamatan dan Kesihatan Pekerjaan (Pengelasan, Pembungkusan dan Pelabelan Bahan Kimia Berbahaya) 1997. Pool operators shall consult with this authority for precise requirements.

16.5 Pool operators shall keep and maintain the material or chemical safety data sheet for all chemicals used in pool treatment and be made readily available to pool workers who handle the chemicals.

16.6 Notwithstanding subsection 16.4, some useful tips (general guide) for pool operators for storing and handling pool treatment chemicals are provided as follows:

- Always use adequate Personal Protective Equipment when handling pool chemicals to minimize health or safety risks.
- Do not add chemicals when swimmers are in the water.
- Always follow chemical manufacturer's directions.

- Never mix chemicals together, particularly calcium hypochlorite (cal-hypo) with trichlor tablets (trichloro-s-triazinetrione) in erosion/feeder-type canisters. A fire and/or explosion could result.

- Always add acid to water; never add water to acid.

- Carefully add liquid or dry acid into various areas at the deep end of the pool away from ladders, skimmers, and metal parts. Alternatively, for vinyl liner, fiberglass, smaller pools, and spas, the prescribed quantity of dry acid (sodium bisulphate) should be dissolved in a 2-5 gallon plastic pail of water before adding to the pool or spa. Circulate water for at least 2 hours and retest. Several incremental additions over a 2-day period will be required for larger quantities of acid. As a general rule for pools, do not add more than 946 ml of muriatic acid or 1.1 kg of dry acid per 38,000 litres of pool water per day.

- For spas, the pump should be turned off, and the pre-dissolved acid should then be added and mixed vigorously by turning on the aeration pump (air blower). The purpose of this approach is to prevent a surge of acidic (corrosive) spa water from entering the pump and heater which could result in metal corrosion. Concentrated muriatic acid (liquid) is not recommended for use in spas because it is so highly concentrated and so little is needed. For spas, do not add more than 28 g of dry acid per 1,900 litres of spa water at any one time. After 30 minutes, retest. Additional acid may then be added to the spa.

- Muriatic acid liquid (about 30%) is concentrated and very corrosive. Dry acid (sodium bisulphate) is also very corrosive. Handle acid very carefully. Rinse plastic dispensing containers with water after use. Wear protective eyewear. Wash away spills thoroughly with water. Keep material away from children. Do not get on skin, in eyes, or on clothing. In case of contact, immediately flush eyes or skin with large amounts of water for 15 minutes. Call a physician.

- Calcium hypochlorite (granular or tablets), 10% sodium hypochlorite (liquid), and lithium hypochlorite (granular) are all very alkaline materials and the same handling precautions outlined for acids should be followed.

- Never store acids and chlorine compounds next to each other.

- All chemicals used for any purpose in or around the pool should be handled very carefully and precautions noted by the manufacturer followed.

17.0 REFERENCES

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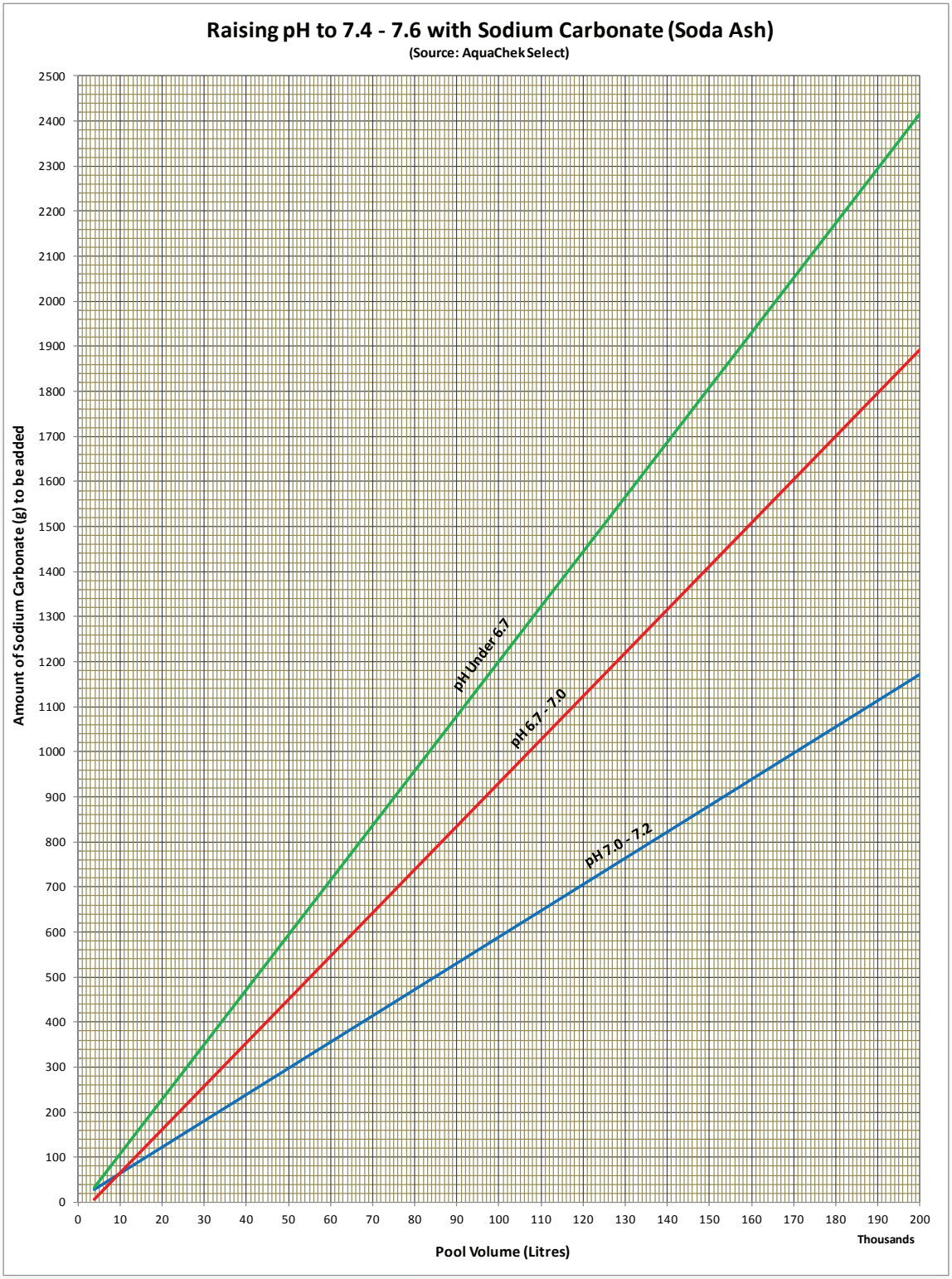
15. Health Canada, Standard Placed. Personal Communications via Canadian High Comm., Kuala Lumpur.

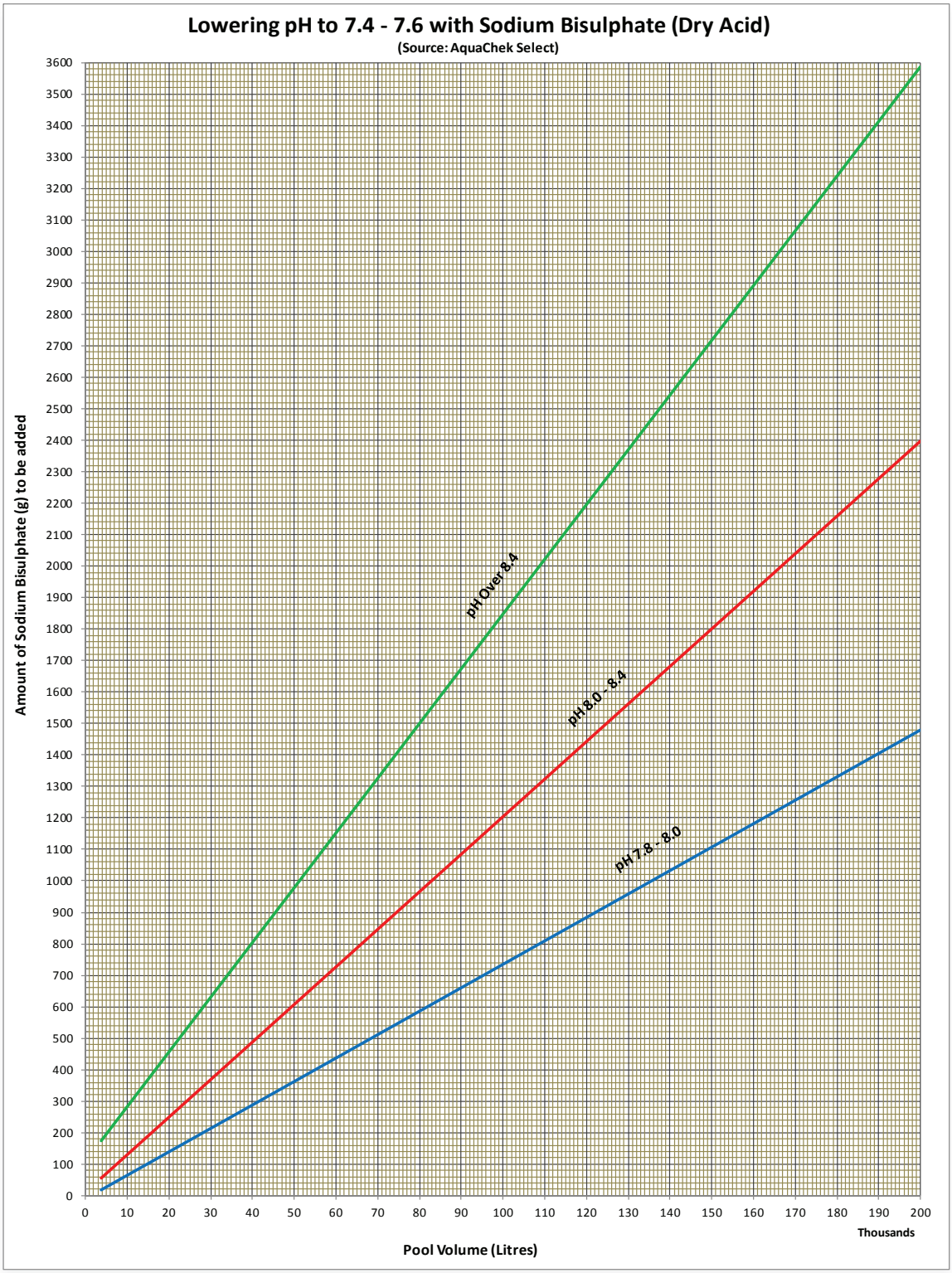
APPENDIX 1



pH level	Estimated Amount of Sodium Carbonate (g) to be added
Under 6.7	(0.0121 x Pool Volume) - 6
6.7 - 7.0	(0.0096 x Pool Volume) - 15
7.0 - 7.2	(0.0058 x Pool Volume) + 5

Note: Pool volume is in litres.

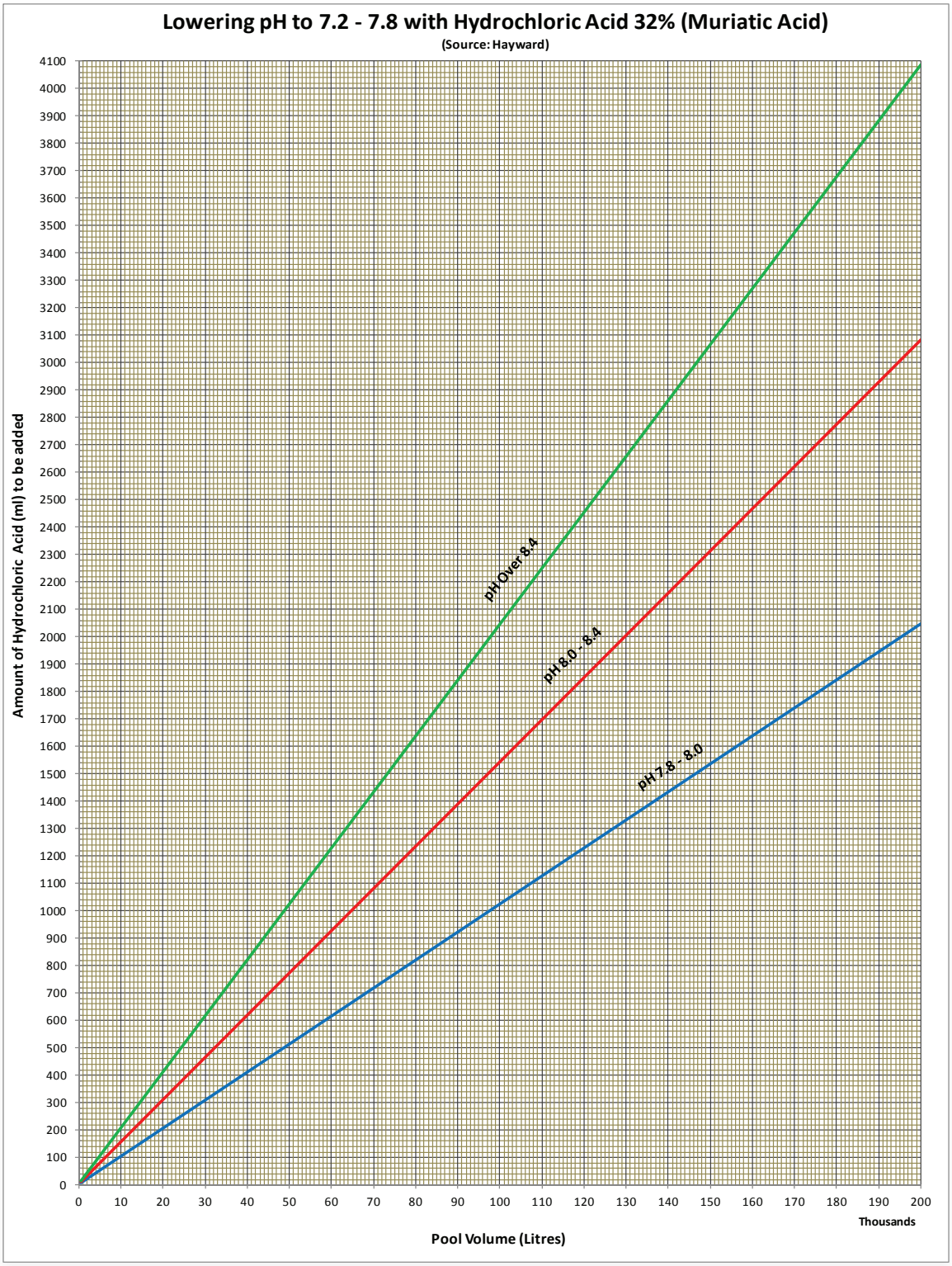
APPENDIX 2



pH level	Estimated Amount of Sodium Bisulphate (g) to be added
7.8 - 8.0	(0.0075 x Pool Volume) - 11
8.0 - 8.4	(0.0119 x Pool Volume) + 11
Over 8.4	(0.0174 x Pool Volume) + 110

Note: Pool volume is in litres.

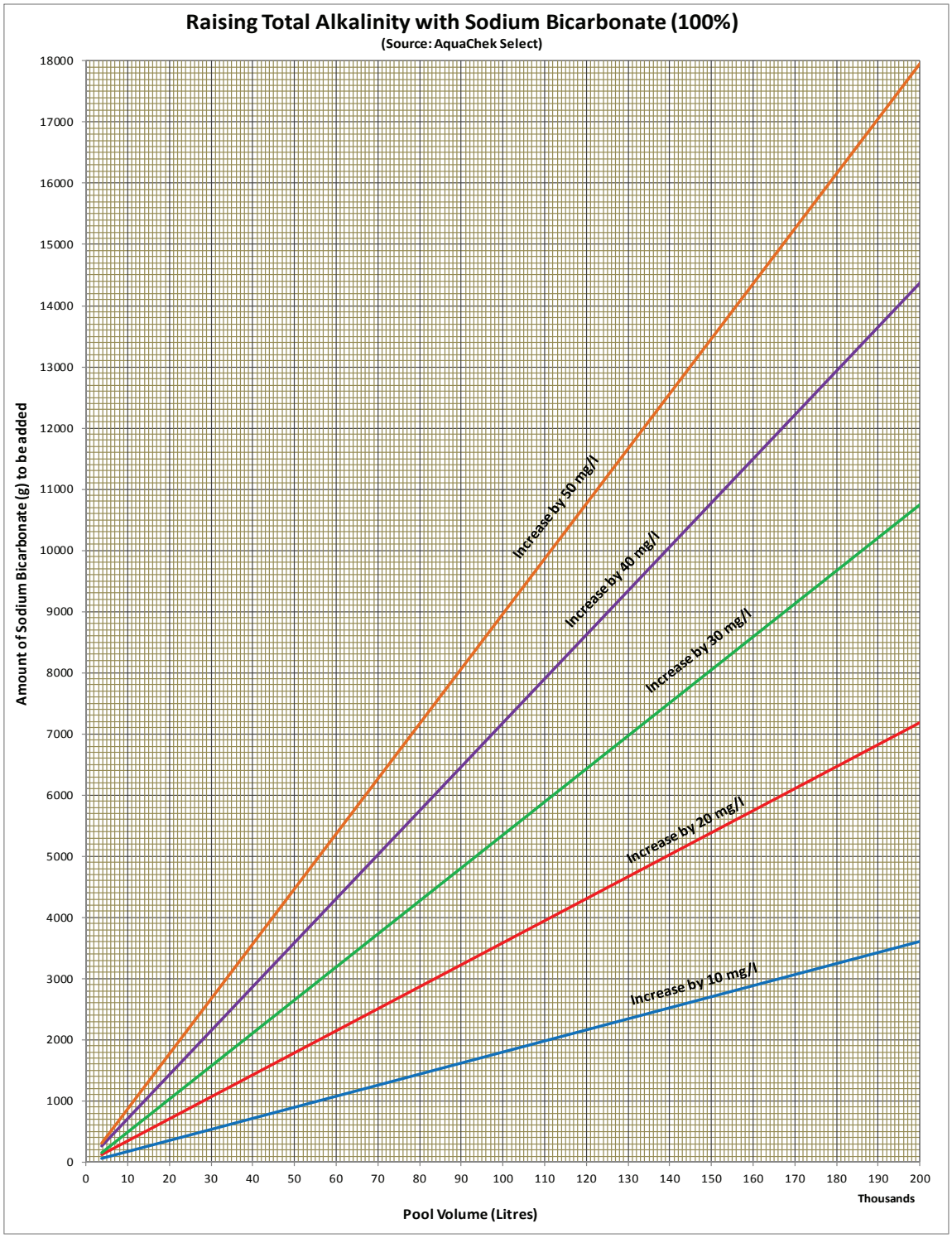
APPENDIX 3



pH level	Estimated Amount of Hydrochloric Acid (ml) to be added
7.8 - 8.0	(0.0102 x Pool Volume) + 4
8.0 - 8.4	(0.0154 x Pool Volume) + 7
Over 8.4	(0.0204 x Pool Volume) + 7

Note: Pool volume is in litres.

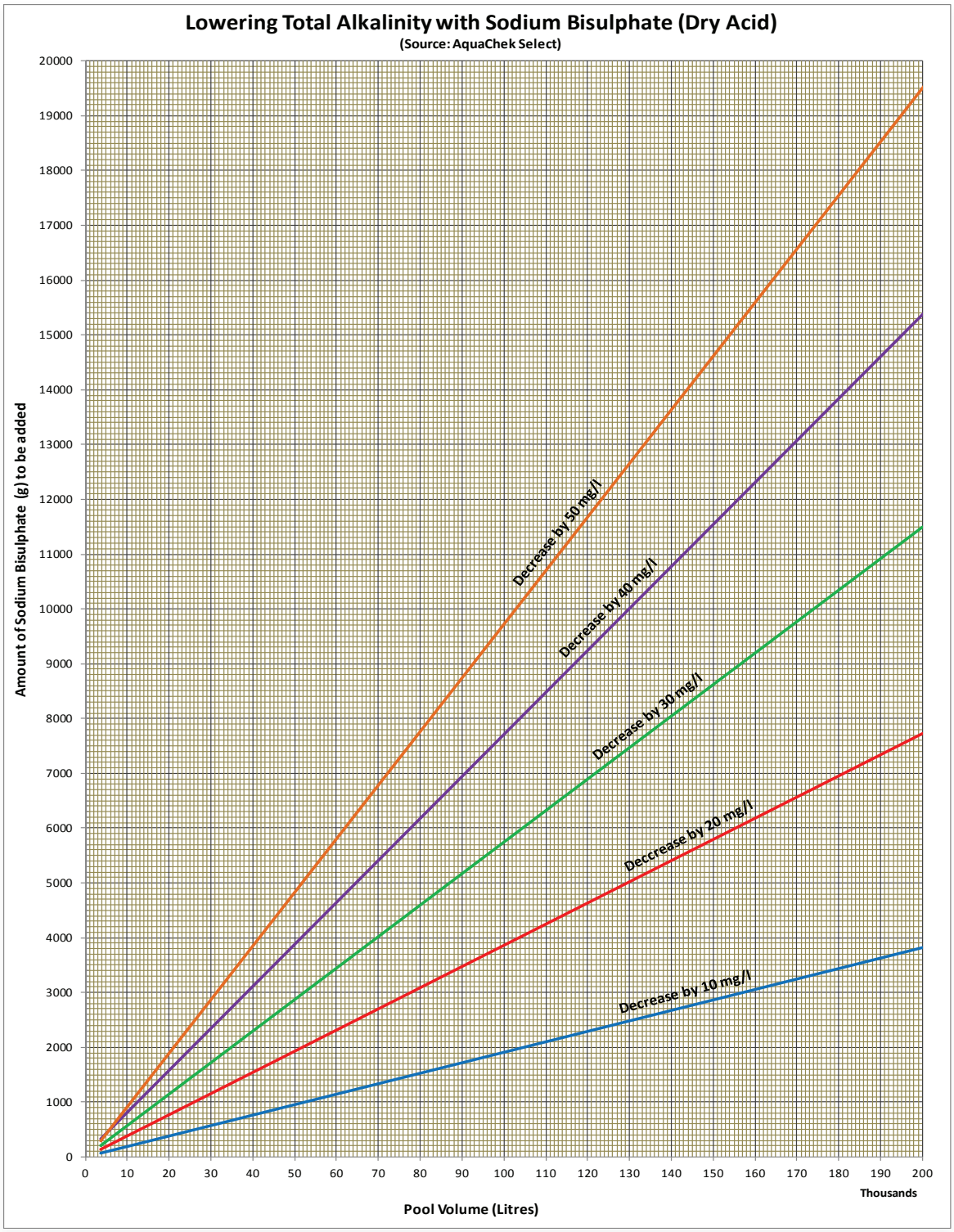
APPENDIX 4



Increase in Total Alkalinity (mg/l)	Estimated Amount of Sodium Bicarbonate (g) to be added
10	(0.018 x Pool Volume) - 4
20	(0.0359 x Pool Volume) - 8
30	(0.0539 x Pool Volume) - 53
40	(0.072 x Pool Volume) - 16
50	(0.09 x Pool Volume) - 37

Note: Pool volume is in litres.

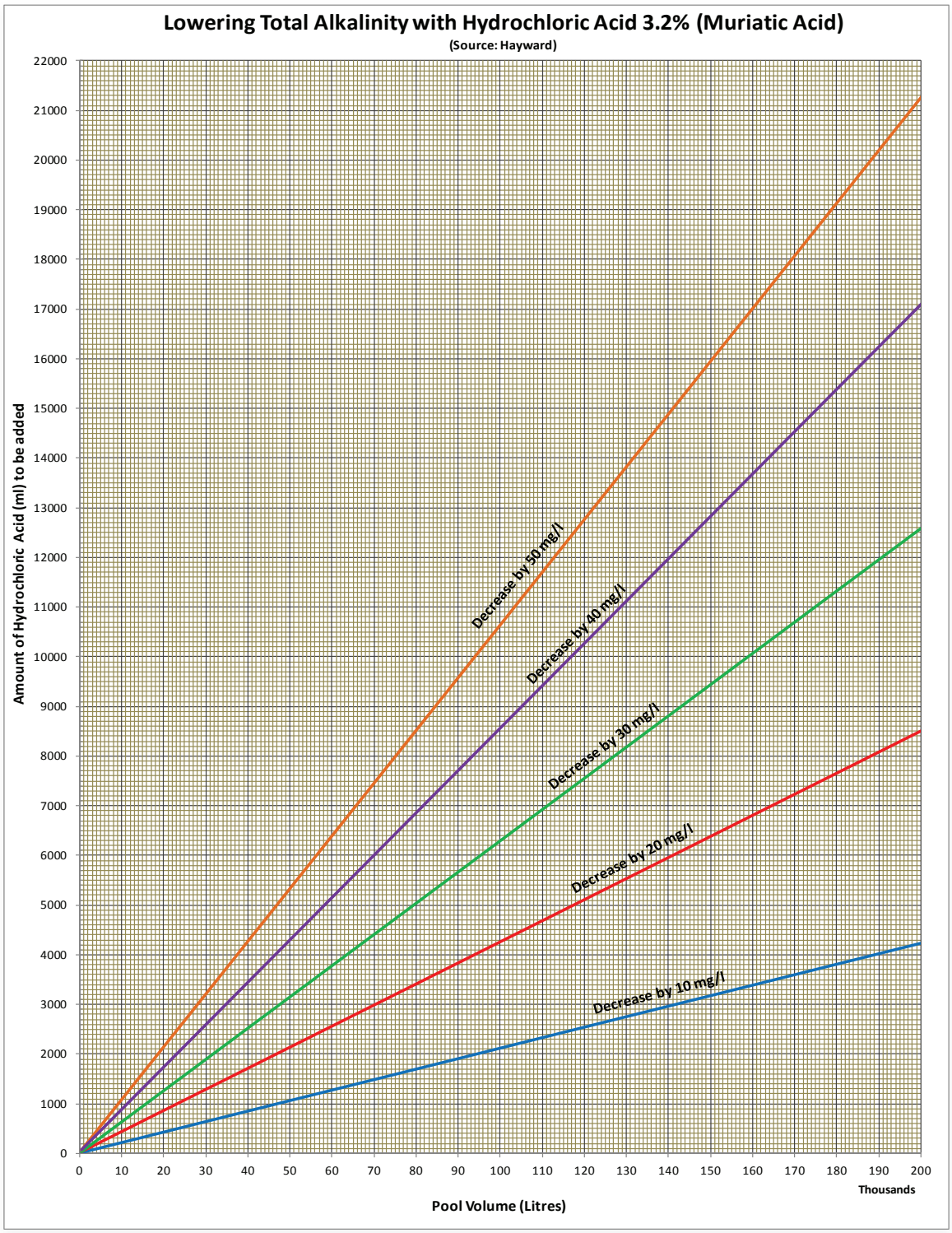
APPENDIX 5



Decrease in Total Alkalinity (mg/l)	Estimated Amount of Sodium Bisulphate (g) to be added
10	(0.0191 x Pool Volume) - 3
20	(0.0387 x Pool Volume) - 6
30	(0.0575 x Pool Volume) - 7
40	(0.0766 x Pool Volume) + 40
50	(0.0978 x Pool Volume) - 69

Note: Pool volume is in litres.

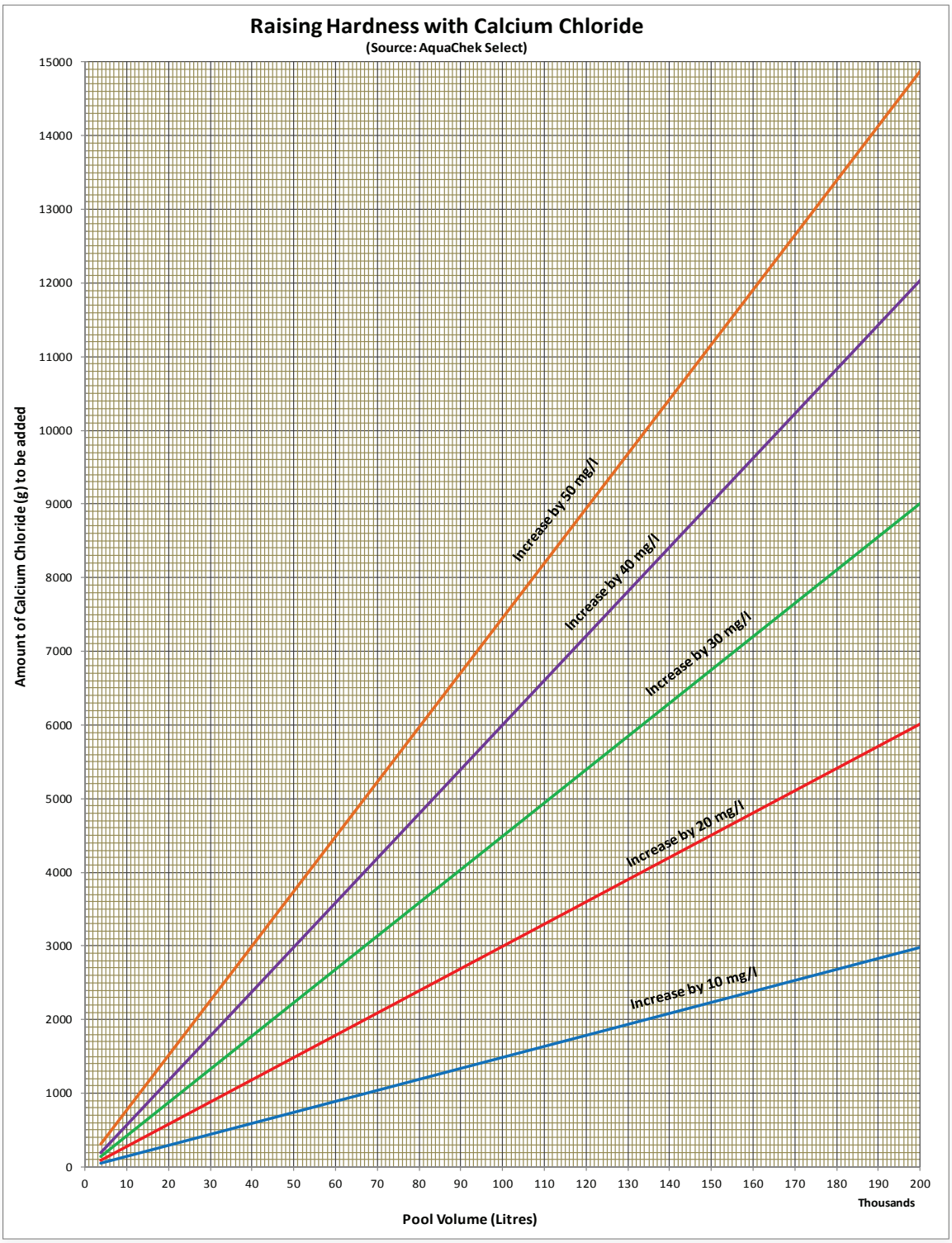
APPENDIX 6



Decrease in Total Alkalinity (mg/l)	Estimated Amount of Hypochloric Acid (ml) to be added
10	(0.0211 x Pool Volume) + 1
20	(0.0425 x Pool Volume) + 14
30	(0.0629 x Pool Volume) + 4
40	(0.0853 x Pool Volume) + 41
50	(0.1061 x Pool Volume) + 26

Note: Pool volume is in litres.

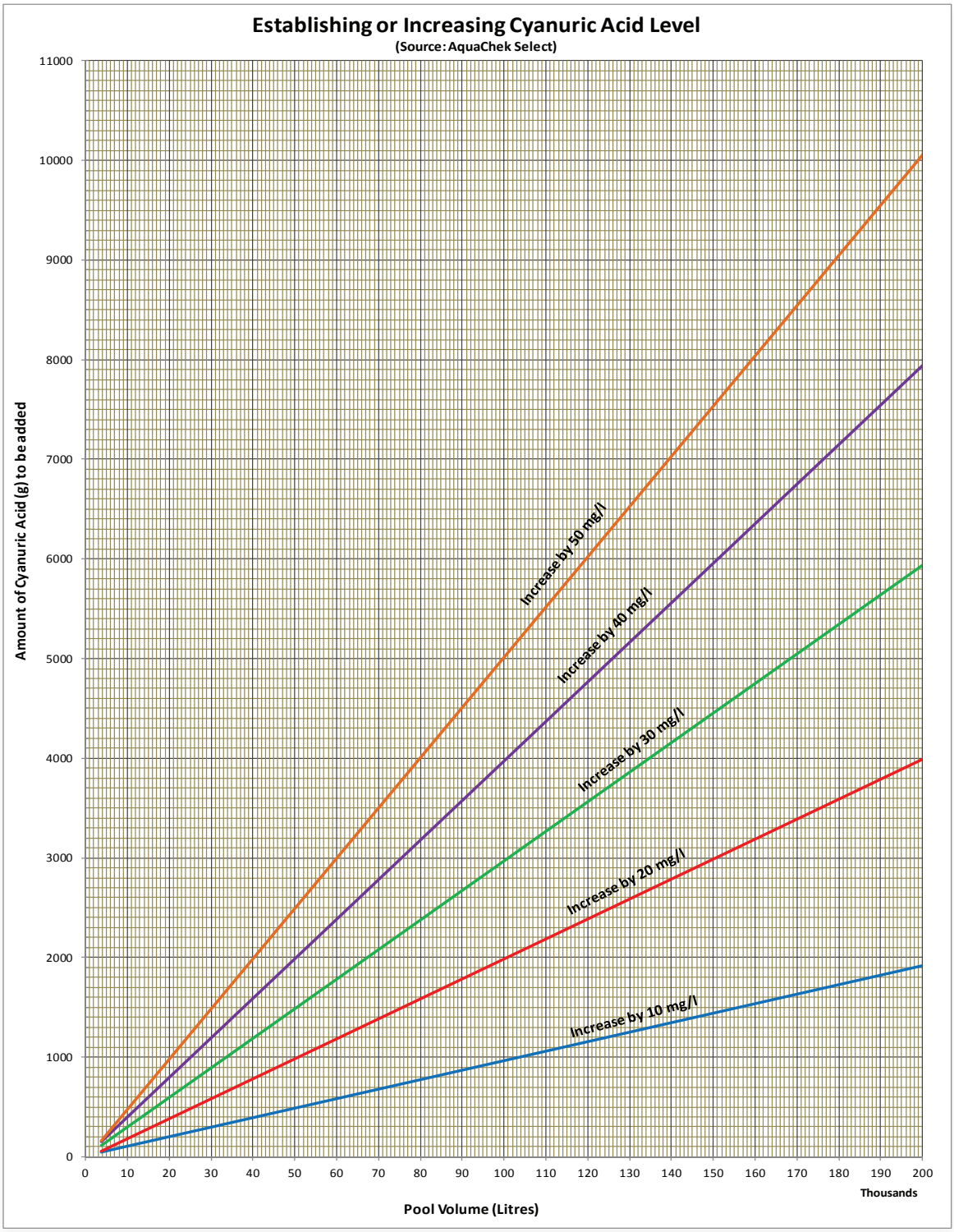
APPENDIX 7



Increase in Hardness (mg/l)	Estimated Amount of Calcium Chloride (g) to be added
10	(0.0149 x Pool Volume) - 4
20	(0.0302 x Pool Volume) - 19
30	(0.0452 x Pool Volume) - 31
40	(0.0604 x Pool Volume) - 32
50	(0.0743 x Pool Volume) + 27

Note: Pool volume is in litres.

APPENDIX 8



Increase in Cyanuric Acid (mg/l)	Estimated Amount of Cyanuric Acid (g) to be added
10	(0.0095 x Pool Volume) + 9
20	(0.02 x Pool Volume) - 22
30	(0.0296 x Pool Volume) + 2
40	(0.0397 x Pool Volume) + 5
50	(0.0505 x Pool Volume) - 31

Note: Pool volume is in litres.