Swimming pool issues

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Introduction

Swimming is an enjoyable, healthy activity performed by millions of people worldwide. There is however a growing body of evidence about a number of health risk associated with swimming (besides drowning or impact injury).
These risks fall into two categories:

1 Infection
2 Chemical exposures and poisoning from pool sanitizing agent(s).

Infection
Sanitizing is an important aspect of a swimming pool. It makes the pool water safe to swim in by killing potential pathogens and inhibiting their growth.

Chemicals used
The principal sanitizing agent in most countries is chlorine. This can be liquid, powder or salt chlorinator generated. Chlorine has been used for many years and there are a lot of studies done which demonstrate both the efficacy and safety of it.
However, there are a number of issues in relation to both of these topics, (efficacy/safety) and the long-term exposure to chlorine by-products.

Efficacy
Chlorine effectiveness is inversely affected by
pH
Air and water temperature
Bather load
Sunlight
This means that the above-mentioned conditions all have an effect of the effectiveness of chlorine. For example at pH 8.0 chlorine is only some 15% efficient. High temperature and sunlight also depletes the chlorine. There are also some pathogens like Giardia and Cryptosporidium, which for chlorine to kill require dosing levels far in excess of what is considered safe for humans. Chlorine is also known to have poor result on controlling bio-film. (Bio-film is where pathogens live)

Safety
As mentioned before there are many studies done and papers published which demonstrate the safety of chlorine. The problem is that the majority of these studies only look at chlorine and not at the large number of it's by-products, which are formed by the interaction of chlorine and organic matter in the water.
For example, the World Health Organization in their guideline for recreational waters quoting from studies which indicate, that a 60 minutes swim in chlorinated pools causes a THM absorption, which is equal to 141 ten minutes showers. A five minutes shower has the same effect as drinking 8 glasses of chlorinated water, so 141 x ten minutes showers is equal to 141x2x8=2240 glasses of chlorinated water. Many people these days do not drink tap water because of the concern of chlorine and other chemicals. They effort will go in vain though with the effect of chlorine through showering and swimming in chlorinated water.

We hope that the information in this publication will be useful to make a healthier environment for you.

swimming pool issues

Chapter one : swimming pool issues

The regulatory bodies in Australia whose job it is to regulate swimming pools have to make sure that spa's; domestic and public pools are safe from the sanitation point of view.

This is important since the quality of the water can have a real and present danger for those who swim in it.
This paper attempts to investigate the various aspects that makes pool and spa water safe.
To do this we need to take into consideration the available scientific data and the many years of experience of the related industries.

The type of hazards related to recreational swimming in a spa or swimming pool environment :

Type of negative health outcome associated with exposure to a hazard	**Examples (with chapter references in parentheses)**
Drowning and near-drowning	Swimmers under the influence of alcohol; poor swimming ability; no supervision; diving accidents; entrapment (2).
Major and minor impact injuries	Impact against hard surfaces (2). The impact may be driven by the participant (diving, accidents arising from the use of water slides, collision, treading on broken glass and jagged metal — especially in outdoor pool surrounds).
Physiological	- Acute exposure to heat and ultraviolet (UV) radiation in sunlight — heat exhaustion, sunburn, sunstroke in outdoor pools (refer to Volume 1 of the Guidelines). - Cumulative exposure to sun for outdoor pool users — skin cancers (basal and squamous cell carcinoma, melanoma) (refer to Volume 1 of the Guidelines). - Heat exposure in spas or cold exposure in plunge pools (2).
Infection	Ingestion of, inhalation of or contact with pathogenic bacteria, viruses, fungi and protozoa, which may be present in water and pool surrounds as a result of faecal contamination, carried by participants or animals using the water or naturally present (3).
Poisoning	Ingestion of, inhalation of or contact with chemically contaminated water, and inhalation of chemically contaminated air (4).

Source World Health Organisation (WHO).

In this paper the discussion is focussed on the sanitation part ie the last two items listed in the table : infections and poisoning.

1 Infections

Infections have several influencing factors :
A Pool design
B Operational conditions

C Water quality
D Introduction of pathogens
E Environmental conditions
F The individual(s) immune response

The combination of these six factors will produce a site-specific unique condition to each pool or spa due to the different variables.
There is a challenge to the regulators to provide the legislative framework that will ensure a safe swimming environment.

The operator wants a clear easy to follow guideline which when it is followed provide consistently the same predictable outcome. But is that achievable with that many variables ? Can a reductionist methodology work in a constantly changing dynamic environment?
If our objective is the well being of the swimmers, we might need to look at this challenge with a more comprehensive approach.
It would be nice to have a simple system where the operator just needs to make sure that there is enough chlorine in the water, which will guarantee safe conditions. Alas that is not the case.
A study conducted in Europe showed that 66.7% of water entering public pools and 91.7% leaving pools had microbacteria in it and filtration and chlorination only brought about a slight reduction in the microbacteria count.
Source Leoni E, Legnani P, Mucci MT, Pirani R. J Appl Microbiol (1999) **87**(5) p683-688.

Chlorine is not an all in one solution for water quality and there are a number of things that will mitigate the effectiveness of chlorine.

1.A Pool design

This is an important aspect of a pool since if it is not designed properly it will make maintenance very difficult, even if everything else done properly.
This includes the circulation, filtration, sanitation etc

1.A.1 Circulation

It is important that the pool has enough jets and returns and that there is a sufficient number of well positioned skimmers or a properly designed negative edge in use for good circulation.

1.A.2 Filtration

Filtration is critical to remove solids from the water. Most filters are sand based in a public swimming pool environment, though Zeolite is now becoming the choice of many pool operators. DE-filters are not often used in large public pools because of the high maintenance issues, although they have a much better particle size since they can filter down to 3-5 micron. Zeolite has many benefits as it matches the filter capacity of DE but also features Ammonia reduction, some bacteria filtration, some Protozoa filtration, dead skin and blood filtration, easier maintenance and longer filter cycles (less frequent need for backwashing)

A word on bio-fouling

The function of any pressure filter is the removal of solids from the water. Solids may be organic or inorganic in nature, or in different terms, solids can be either digestable by bacteria or not.

In a sand filter the non-biodegradable solids do not present a problem since they will generally be removed during the next back flush. The problem are the solids that will break down in the filter as a consequence of bacterial activity. A sand filter cannot remove dissolved organics, fats, urea etc, and they also act as a food source for bacteria.

Any surface in a pool or spa in contact with water will have a film of bacteria; this film develops very rapidly over a period of hours or days. This can not be avoided, the vast majority of the bacteria will be harmless, however the greater the concentration of bacteria, the more likelihood there will be that some of the bacteria could be potentially dangerous. Hygiene is therefore paramount, and all surfaces should be regularly cleaned or scrubbed to remove the surface film. There are areas that cannot be cleaned, such as the inside of pipes.. Bacteria can also develop in the pool water itself.
When bacteria are in suspension, they are easier to kill by chlorine or ozone present in the water. However, as soon as the bacteria become fixed to a surface, they excrete a protective coat, and the levels of chlorine conventionally used in pool water will have little effect. Research conducted by the Institute of Food Research has shown that bacteria will form a firm bond with a substrate in less than 20 seconds. Levels in excess of 100 mg/l chlorine will not provide complete disinfection of the sand surface. Chlorine has been known for poor performance in bio film control in the industry for a long time.

Ozone & UV in relation to filter media.

In order to improve the water quality problems resulting from high rate filtration systems, ozone and UV may be employed. Both ozone and UV will disinfect the water, however the process will also crack organic molecules. For example, if a large organic molecule is broken down to too small organic components, then these components will either act as a food source for bacteria, or they will combine with chlorine to form elevated levels of THM. Unless ozone or UV is used to oxidise organics back to carbon dioxide, they will simply make matters worse by increasing the combined chlorine level, THM and possibly also the bacterial levels. Ozone and UV may have a role to play is swimming pools, but the filtration system should be right before any additional high costs systems are considered.
Again the point to remember is that the different components will have an effect on all the other components too
For the above reason a laboratory test which test one component only is not always the best indicator to the efficacy of a system.

Sanitation
Sanitation is the most regulated part of a swimming pool or spa.
There are a number of different systems in use, each with some benefits and disadvantages.
Chlorination
Bromine
Baquacil
Ozone
UV
Ionizers
Dual or multistage sanitizers

Chlorine
The world standard is still based on chlorine since it has the longest scientifically documented history and it's broad spectrum pathogen kill rate.
Many different forms are in use.
Chlorine gas
Sodium chlorite
Calcium Hypochlorite
Chlorine Dioxide

Chlorine is working in specific pH ranges and is heavily dependent on this parameter: its effectiveness is down to 20 % at pH 8. At pH 8.5 it's only 5-8% efficient. Therefore it is very important to keep the pH within the right range.
Chlorine also reacts with UV and sunshine and it only takes a few hours to deplete most of it from the water even with automatic chlorination.
There are also a growing number of pathogens that have developed some resistance to chlorine. For this reason there is a movement towards using a combination of sanitizers or Dual or Multistage systems.

Ozone
Ozone has been used for many years worldwide. Ozone has the fourth highest Oxidation Reduction Potential from all the elements and this ORP is much higher than any form of chlorine that is used for sanitation. For this reasons it has the ability to kill pathogens very quickly. There is however a downside too. Ozone does not provide any residual protection and therefore it is usually used with some other form of sanitation. Nevertheless there is at least one public swimming pool in the USA, which runs on a standalone ozone sanitizer, which seems to be doing its job satisfactorily.

UV
Ultraviolet light kill pathogens by a photochemical process. It is effective but has similar limitations as ozone. For this reason it is used in conjunction with other sanitation agent(s).

Ionization
Ionization is also an old proven technology developed by Honeywell Corporation in the sixties for the Apollo space program. It employs copper, silver or the combination of the two (sometimes even other metals) metallic ions as active biocides. There are many published

papers on the efficacy of ionizers and they been used in tens of thousands of pools all around the world. Some of the benefits are
More stable than chlorine
Long residual protection
Non toxic
Better quality water and higher swimmers satisfaction.
There is no oxidation however and for that reason ionisation cannot be used as a stand-alone sanitizer. Usually it is used with some form of oxidation agent.
There is a lot of evidence in favour of the combination of low-level chlorine with an ionizer as the best method to provide a safe swimming environment in public pools. (See Studies and Published Papers On Ionization by INWA)

Dual or Multistage Sanitizers
Dual or Multistage sanitizers are becoming more and more popular because scientific data shows that it is easier to ensure safe water, free from pathogens with a combination of different systems than with any one method alone.
There are pros and cons for each individual system and a well-designed Dual or Multistage system may offer a better result.

1.B Operational Conditions
Even the best-designed pool will not operate well if proper operational conditions are not ensured. These are
Appropriate bather load
Pool chemistry
Maintenance
Monitoring

These are really common sense points.

1.B.1 Appropriate bather load

An over crowded pool potentially creates a dangerous situation from more than one point of view: drowning or near-drowning, major or minor impact injuries and infection

1.B.2 Pool chemistry

For any sanitation system to work the water chemistry parameters need to be maintained within the prescribed range. This is also important for swimmers comfort and health.

1.B.3 Maintenance

Maintenance is critical and includes the following: grounds, pool, lockers and changing rooms, toilets and equipment
All of these have an effect on infection directly or indirectly.

1.B.4 Monitoring

Monitoring is also important so that operators and regulators can have a good idea of the prevailing conditions of the pool. The sanitation system should have an automatic monitoring and dosing system in place so that the pool chemistry and sanitation is the most predictable.

1.C. Water quality

Water quality is influenced by a number of factors. Source water, bather load, environmental conditions and many others. The operator needs to make sure that the water quality is maintained at all times, by insuring good water chemistry and by maintaining proper operating conditions.

1.D Introduction of pathogens

This is mostly beyond the control of the operators though there are thing to do to minimise the risk. : Public education and good hygienic practices

1.E Environmental Conditions

These are sun rain temperature etc mostly beyond the control of the operators though some can be mitigated by design and construction.

1.F Individual immune response

This is the most difficult to influence and really the only thing the operator can do is to use less toxic chemicals to minimise the effect on the immune system of the swimmers.

2 Poisoning

This can happen from two sources in a pool environment.

Ingestion of, inhalation of or contact with chemically contaminated water, (sanitation by-product) inhalation of chemically contaminated air from the sanitizing by-products in a normal course of using the pool.

Or

Ingestion of, inhalation of or contact with chemically contaminated water, and inhalation of chemically contaminated air from the sanitizing agents by accident.

There are literally hundreds of studies on the effect on swimmers from the sanitising by-products, such as chloramines and THM. See Chlorine Issues by INWA

The chemicals used in and around swimming pools can be highly toxic so it is very important to insure safe storage, transportation and handling.

There is a lot of accumulated knowledge in the swimming pool industry and in the scientific world. The best outcome will come if we learn to integrate the two.

Recommended reading.
Guidelines for Safe Recreational-water Environments. World Health Organization
Studies And Published Papers INWA
Chlorine Issues INWA
The Copper Files INWA
Swimming Pool Use Linked to Asthma Rise The Australian (AFP) 29 May 2003
Bronchospasm in competitive swimmers Reuters Health, March 21, 2001.

"The EPA has raised skin absorption of chlorine to its top 10 carcinogen watch list."
The Washington Post June 1994
"Showering is suspected as the primary cause of elevated levels of chloroform in nearly every home because of the chlorine in the water."
American Journal of Public Health - Dr.Halina Brown

Dental Enamel Erosion Increased in Competitive Swimmers in Chlorinated Pools
American Journal of Epidemiology, 123(4), 641-647.

Young Swimmers at Greatest Health Risk in Chlorinated Indoor Pools
Toxicology Letters, 72(1-3), 375-380.

Chlorine Product Absorption in Swimmers is Greatest via The Skin
Environmental Health Perspectives, 105(6), 636-642

Tap Water-Miscarriage Link Found
Associated Press February 11. 1998

Chlorine issues

Chapter two : Chlorine Issues (published papers on chlorine)

World Health Organization Guidelines for Safe Recreational Waters
Volume 2 - Swimming pools, spas and similar recreational-water environments
4.2.4 Measured and estimated exposures by all routes

Several studies have estimated intake and uptake of chloroform or other THM compounds in persons exposed in pool environments. THMs are expected to be good surrogates for other volatile substances with similar physical/chemical properties (e.g., trichloramine, chloroacetonitrile).

Beech (1980) carried out a study on a six-year-old boy immersed in water containing 500 m g chloroform per litre for 1 h. They estimated that his exposure corresponding to a 3-h session would be as follows: dermal 1.65 mg; oral 0.079 mg; buccal and sublingual 0.075 mg; orbital and nasal 0.07 mg; aural 0.075 mg; inhalation 0.866 mg: total 2.82 mg.

Shatkin & Brown (1991) calculated dermal absorption rates of chloroform by a swimmer during a 20-min immersion in pool water and estimated a total dose as high as 4.8 mg. Kaas & Rudiengaard (1988) calculated that dermal absorption of 700 m g of chloroform and oral absorption of 200 m g could occur from a 1-h swim in water containing 150 m g/litre and suggested an inhalation dose of 12.9 mg chloroform from a 2-h swim.

Lahl et al. (1981) estimated inhalation exposures and uptakes in two scenarios, assuming a respiration volume of 1 m3/h and 50% uptake of inhaled chemical. They estimated that a dose of 50 m g of chloroform would be absorbed in a 30-min swim during a 1-h visit inhaling air just above the water surface. Using more extreme conditions, i.e., a 1-h swimming session, maximum water/air exchange of chloroform, chloroform concentrations of 389 m g/m3 in air, and spending 10 min resting above the water discharge port with maximum chloroform out gassing, they estimated a burden of 500 m g of chloroform per person per visit (about 7 m g/kg for a 70-kg adult). [IPCS (1994), based on ICRP (1974), considers the average body weight of an adult to be 64 kg, based on body weights of 70 kg for an adult male and 58 kg for an adult female. The WHO Guidelines for Drinking-water Quality (WHO, 1993) uses 60 kg for an adult body weight.] For children, they estimated a specific dose of 15 m g/kg body weight. All of these estimates are for inhalation exposures alone.

Lévesque et al. (1994) estimated that the daily dose of chloroform resulting from a 1-h swim (65 µg/kg body weight per day) in conditions commonly found in public swimming pools is 141 times greater than that for a 10-min shower and 93 times greater than that for tap water ingestion.

Lindstrom et al. (1997) measured chloroform and BDCM in breath from two collegiate swimmers during a 2-h training session and 3 h afterward. They concluded that 80% of the blood chloroform concentration was attributable to dermal exposure. This conclusion was based upon comparisons of the concentration of chloroform in the swimmers' exhaled breath with the ambient pool air concentration. They did not measure chloroform levels in the air in the breathing zone close to the water surface.

"While swim training may improve fitness and reduce morbidity associated with asthma, there is both anecdotal and scientific information to suggest that there are health-related problems associated with swimming in chemically-treated pool water. Swimming pool water is disinfected in the interests of public health, ***although it would appear that chemical disinfection of the pool water may be the cause of many of the health-related problems that have been reported.*** There is medical evidence suggesting that exposure to chemicals such as chlorine and its derivatives, chloramines or chloroform may damage the respiratory epithelium and cause increased vascular permeability and oedema of the mucous membranes lining the airways and lung, both of which may result in severe inflammatory reactions."
Sports Medicine [SPORTS MED.], vol. 21, no. 4, pp. 256-261, 1996

Title: ERS: **European Investigators Identify Potential Cause of Asthma in Swimmers**
Doctor's Guide
September 28, 2001
By Cameron Johnston
Special to DG News
BERLIN, GERMANY -- September 28, 2001 -- European investigators at two different centres have identified what might be the trigger that causes asthma in swimmers more than many other athletes.
During the Olympic Games held in Australia, last year, it was reported that more than one-quarter of the American swim team suffered from some degree of asthma.
In separate presentations at the European Respiratory Society meeting, held this week in Berlin, Dr. K. Thickett, of the Occupational Lung Diseases Unit at the Birmingham Heartlands Hospital, Birmingham, England, said it is not only the exposure to the chlorine that is the culprit causing asthma in swimmers.
More important, she said, is the chemical reaction that occurs when chlorine comes into contact with sweat and urine, and releases derivatives such as aldehydes, halogenated hydrocarbons, and chloramines.
As part of Dr. Thickett's study, three employees of a local public swimming pool who complained of asthma-like symptoms were subjected to chloramine challenge tests in which, in the lab setting, they were exposed to roughly the same amounts of chloramine as they would be exposed at work (i.e., around the swimming pool, close to the surface of the water). Measurements of nitrogen trichloride were taken 15 points around the pool, 1 m above the surface of the water.
When exposed to equivalent amounts of the chemical in the lab, the three subjects all experienced significant reductions in forced expiratory volume in one second (FEV1), and high measurements on their Occupational Asthma Expert System (OASYS) scores, a measurement of asthma and allergy severity.
"Our results show, indeed, that nitrogen trichloride is a cause of occupational asthma in swimming pool workers like lifeguards and swim instructors."
"We used to think that chloramines caused only eye and throat irritation, and while other studies have hinted that there might be a connection between chloramines and respiratory irritation, this is the first to demonstrate a causal effect on the basis of a bronchial challenge test."
In Dr. Thickett's study, each of the subjects either stopped taking inhaled corticosteroids altogether, or their asthma symptoms resolved significantly once they were placed in other occupations away from the swimming pools.

Meanwhile, investigators in Belgium and Australia presented research showing that exposure to such chloramines greatly increases permeability of the lung epithelium.
In the study presented by Dr. Simone Carbonnelle, of the industrial toxicology and occupational medicine unit at the Catholic University of Louvain, in Brussels, 226 otherwise healthy school children, mean age 10, were followed to determine how much time they spent around swimming pools, and the condition of their lung epithelium.
As with the British study, chloramines in the air around the surface of the pool were measured. In addition, three specific proteins were measured in the children: SF-A and SF-B (surfactant A and B) and Clara cell protein 16 (CC16).
Surfactant A and B are lipid-protein structures which enhance the bio-physical activity of lungs lessening surface tension in the lung epithelium and preventing the collapse of the alveoli at the end of expiration. Anything that impairs the function of these surfactants will clearly impair lung function as well, because it makes the epithelium more permeable.
The children in Dr. Carbonnelle's study were exposed to air around the school swimming pool for a mean of 1.8 hours per week. It was then observed that there was a significant variance in the levels of SF-A and SF-B as well as CC16 that were directly proportional to the amount of time the children spent around the pool. For SF-B, the variance was 11.6 percent, which according to Dr. Carbonnelle, would be the equivalent of what she would expect to see in a heavy smoker.
The variation in lung surfactants persisted whether the children lived in a rural area or in the city, and whether they were from upper income, or less well-off families, she added.
"These findings suggest that the increasing exposure to chlorine-based disinfectants used in swimming pools and their by-products might be an unsuspected risk factor in the rising incidence of childhood asthma and allergic diseases," she said.
Source: Women's Health Weekly, Jan 31, 2002 p16.

Title: **New Study Warns Pregnant Women Millions Drink Contaminated Water**.

Subjects: Drinking water - Contamination
Pregnant women - Health aspects
Locations: United States

2002 JAN 31 - (NewsRx.com & NewsRx.net) -- Millions of Americans have been drinking tap water contaminated with chemical chlorine by-products that are far more than what studies suggest may be safe for pregnant women, two environmental groups say in a new study.
Chlorine is commonly used to disinfect drinking water. When it is added to water that contains organic matter such as runoff from farms or lawns, however, it can form compounds such as chloroform that can cause illness.
The study released January 8, 2002, by the Environmental Working Group and Public Interest Research Groups identified areas that may have increased health risks including miscarriage, neural tube defects and reduced foetal growth from women drinking chlorination by-products.
"By failing to clean up rivers and reservoirs that provide drinking water for hundreds of millions of Americans, EPA and the Congress have forced water utilities to chlorinate water that is contaminated with animal waste, sewage, fertilizer, algae and sediment," the report says.

Jane Houlihan, EWG's research director, said the report also shows how that cleanup failure has "a direct impact on human health." Pregnant women need to drink plenty of water, she said, but they can reduce their exposure to potential risks through simple measures such as home filters and purchasing bottled water.

One expert on environmental health cautioned that the link between the by-products and pregnancy risks is suggestive, not conclusive.

Still, if the pregnancy studies are proved, millions could be at risk, said Dr. Robert Morris, an environmental epidemiologist at Tufts University School of Medicine in Boston, Massachusetts.

"That body of literature isn't necessarily conclusive but people ought to be aware of it," Morris said. "It's pretty clear that some of these compounds can be pretty bad actors. The fact that these levels are as high as they are is certainly something to be concerned about."

The environmental groups combed water quality records in 29 states and the District of Columbia and matched them with various research into birth defects and miscarriages conducted by state and federal agencies and universities.

The groups said the places statistically most at risk due to chlorination by-products were those that are populous, lacked buffers from urban sprawl and were downstream from agricultural sites. But women in small towns generally face twice the risk from drinking high levels of the by-products, Houlihan said.

Matching high rates doesn't prove the environmental risk caused the health problems, however. Also, the results are limited because, among other reasons, such health records do not exist in some states.

The Environmental Protection Agency already has decided that some chlorination by-products pose health risks and instituted stricter standards on January 1, 2002, for seven of them: five haloacetic acids, bromate and chlorite. The agency also began requiring a reduction by one-fifth of the allowable level for trihalomethanes, another chemical produced by adding chlorine to dirty water.

EPA studies showed that reducing the level of trihalomethanes might mean 2332 fewer cases of bladder cancer per year, down from its estimate of up to 9300 annual cases caused by trihalomethanes.

While the environmental groups said the majority of water suppliers were meeting the current and future drinking water health standards, they also found that since 1995 more than 11 million people in 1044 communities were being served water contaminated with chlorination by-products for 12 months in a row at levels above the new legal limit.

To reduce the risks, the groups said, the federal government should provide billions of dollars more for cleaning up sources of contaminated water and providing more buffer areas that can filter potential contaminants from farmland and urban areas.

This article was prepared by Women's Health Weekly editors from staff and other reports.

Tap Water-Miscarriage Link Found

Associated Press (February 11, 1998)

LOS ANGELES (AP) -- Pregnant women in their first trimester who drink five or more glasses of cold tap water daily may be at higher risk of miscarriage, according to a study of California chlorinated drinking water.

The heightened risk is linked to exposure to a contaminant found in chlorinated water in a majority of municipal water systems nationwide. The chemical -- trihalomethane (TTHM) -- forms when chlorine reacts with acids from plant material.

Chlorine helps purify water and prevents bacterial infections. TTHMs have been associated with increased cancer risk, at least in animals, and federal regulators have limited the amount allowed in drinking water.

The study, led by California health department investigators Kirsten Waller and Shanna Swann, examined the records of 5,144 pregnant women from the Fontana, Santa Clara and Walnut Creek areas.

The study, which will be published in the Feb. 18 issue of the journal Epidemiology, found that women who drank five or more glasses of tap water per day with at least 75 micrograms per liter of TTHMs had an increased risk of miscarriage.

Their risk was calculated at 15.7 percent, compared with 9.5 percent among women who received low exposure. Only about 2 percent of the women were exposed to the highest risk levels, meaning they consumed five or more glasses with at least 75 micrograms per liter.

All the women drank water that met state and federal drinking standards.

``You do run a risk if drinking un boiled water," said S. David Freeman, the general manager of the Los Angeles Department of Water and Power, America's largest municipal utility.

``Nobody knows how high," he said. ``The most practical thing that we've come up with is to tell women in that category to boil some water and put it in the refrigerator."

The Environmental Protection Agency allows up to 100 micrograms of TTHMs per litre. The agency plans to reduce that standard to 80 micrograms in November.

State and federal officials said the study is not definitive and more tests are planned. It is part of an effort by the EPA to balance the need for protection against microbes -- such as those that cause dysentery and cholera -- with the need to keep the dangers of disinfection itself to a minimum.

At the Metropolitan Water District, which supplies most of Southern California outside Los Angeles, officials said the average levels of TTHM are well below those that triggered concern in the study.

But within Los Angeles, the average concentration in tap water exceeds that level. State health officials advised women to heed their doctors' recommendations on fluid intake, but offered other steps.

For example, carbon-filtered tap water can be left standing in the refrigerator for several hours or water can be boiled for a minute and then left to cool. But the study was not large enough to allow researchers to calculate precise effects.

Title: **Chlorine called possible cancer cause**.
(Women's Environmental
Development Organization)
DATELINE: Women's Environment Development Organization
Aided by former congresswoman Bella Abzug, herself a breast cancer survivor, environmentalists started a campaign to discourage use of chemicals made from chlorine as a precaution against the disease.
"Studies have found that women with the highest amounts of these chemicals in their body have breast cancer risks four to 10 times higher than women with lower levels," said Joe Thornton, who wrote a report on the chemicals for the environmental group Greenpeace.
If future studies confirm those numbers, he said, "organochlorines would be among the strongest risk factors for breast cancer ever identified."
Joe Walker, associate director of the Chlorine Chemistry Council, said the industry group is reviewing the report.
"Because breast cancer is such a frightening illness that touches literally all of our lives," he said, "the last thing we want is for women to be alarmed by preliminary findings from selective studies."

Greenpeace and women's groups demanded that organochlorines - chlorine-based chemicals - be phased out worldwide. Many commonly used items, including clear plastic wrap, pesticides and paper, are made with organochlorines.
"We want prevention," said Abzug, who heads the Women's Environment Development Organization. "You cannot get prevention unless there is a basic commitment to research, to funding, to a consciousness that doesn't seem to exist in the cancer agencies in the government or out of government."
"We intend to create that change," she said. "We intend to involve the millions of Americans who care about this - and most people do - into a mighty effort to organize in every community possible."
Dr. Susan Sieber, deputy director of the division of Cancer Etiology at the National Cancer Institute, said the idea that all chlorine-based chemicals should be banned "is nonsense, based on data currently available."
She said two small studies in 1992 contain intriguing findings about the role of chlorine-based chemicals but "they certainly are not definitive evidence that there is a link with breast cancer." The cancer institute is doing such a study, she said.
Abzug said her cancer was caught early and she is well. But breast cancer, she said, is so prevalent that "there isn't a place or a family that hasn't been affected by it ... We have to conduct a crusade and that's what we intend to do."
Thornton conceded there is no definitive scientific proof that organochlorines are behind an increase in breast cancer. But, he said, proof isn't necessary.
"If proof is defined as evidence, beyond any doubt, of a cause-effect link between individual chemicals and the disease ... the answer is no," he said.
"We need not wait for proof before protecting women's health. If we were to wait for proof, we would be treating women as guinea pigs and we would be treating chemical industries as if they had the rights of people."
Thornton said there is no need for chlorine pollution. "Alternatives are available now for all major uses of chlorine, including chlorine-based

plastics, pesticides, solvents, including incineration and the chlorine bleaching of paper."
In the United States alone, 50,000 women die from breast cancer each year, said the 66-page Greenpeace report, printed on 100 percent chlorine-free paper.
It said the buildup of such chlorine-based chemicals as dioxin, PCB and DDT has contaminated the air, water and food chain across the planet in the last half-century and accumulated in people's bodies.
Thornton said a handful of the suspect chemicals already are subject to bans or severe restrictions but thousands of others still are being used freely.
Full content for this article includes table, graph, table and illustration.

Source: Archives of Environmental Health, May-June 1990 v45 n3 p175(5).
Shower filters may be critical THM defence
Study says chlorination by-products are absorbed at high rates in pore

From the July 2002 edition of Water Technology magazine.

Some consumers who are worried about trihalomethanes (THMs), by-products of chlorination that have been associated with health risks, have typically felt that tap-water treatment alone was a full defence.
However, a new study shows that consumers may be more exposed to THMs when they take showers, as opposed to when they drink water.
Researchers at the University of North Carolina (UNC) at Chapel Hill's School of Public Health say THMs can sometimes get into the bloodstream via a shower at levels four times greater than THM levels in tap water.
High THM concentrations have been linked to cancer, miscarriages and other reproductive problems after long-term exposure.
The study — conducted over four weeks in 1999 on 50 women in Cobb County, GA, and Corpus Christi, TX — was done to evaluate whether health workers could use THM levels in drinking water to predict concentrations in people's blood.
THM concentrations in blood were measured before and after showers. Researchers found that after subjects took showers, the THM levels in their bloodstreams were actually four times higher than the THM levels of the water coming out of their taps.
The research showed that THMs were getting into blood as a result of water use, but it could not address whether concentrations were harmful or if they were linked to any health problem, according to Amy M. Miles, a co-author of the report about the study.
Research support came from the American Water Works Research Foundation, Denver; the Centers for Diseases Control and Prevention, Atlanta; and the US Environmental Protection Agency (EPA).
The groups will perform a follow-up study that will include additional variables, such as having each subject shower for a specified amount of time, and showering with the bathroom door closed so no THMs can escape the area, according to Miles.

Title
Factors Associated with Respiratory Problems in Swimmers
Author
Potts, J
Sch. Hum. Kinetics, Univ. British Columbia, Vancouver, BC, Canada
Sports Medicine [SPORTS MED.], vol. 21, no. 4, pp. 256-261, 1996
Abstract
While swim training may improve fitness and reduce morbidity associated with asthma, there is both anecdotal and scientific information to suggest that there are health-related problems associated with swimming in chemically-treated pool water. Swimming pool water is disinfected in the interests of public health, although it would appear that chemical disinfection of the pool water may be the cause of many of the health-related problems that have been reported. There is some medical evidence suggesting that exposure to chemicals such as chlorine and its derivatives, chloramines or chloroform may damage the respiratory epithelium and cause increased vascular permeability and oedema of the mucous membranes lining the airways and lung, both of which may result in severe inflammatory reactions.
Publication Year
1996

29 May 2003
Pool Chlorine Implicated In Childhood Asthma

The chlorine used to disinfect indoor swimming pools may be implicated in the surge of childhood asthma in developed countries, suggests research in Occupational and Environmental Medicine.

Trichloramine, or nitrogen trichloride, a highly concentrated volatile by-product of chlorination, that is readily inhaled and generated during contact between chlorine and organic matter such as urine or sweat, seems to be the culprit.

The research team measured levels of lung proteins (SP-A, SP-B, and CC16) associated with cellular damage in the blood samples of 226 healthy primary school children from rural and urban schools. The children had swum regularly at indoor pools weekly or fortnightly since early childhood.

Blood samples from 16 children, aged between 5 and 14, and 13 adults, aged between 26 and 47, were also analysed before and after a session in an indoor pool to test for the immediacy of the effects of trichloramine.

Finally, the researchers assessed the prevalence of childhood asthma, using data from a survey of almost 2000 children aged between 7 and 14, carried out between 1996 and 1999.

The results showed that regular attendance at indoor swimming pools was consistently and significantly associated with the destruction of the cellular barriers protecting the deep lung (respiratory epithelium), making them "leaky" and potentially more vulnerable to the passage of allergens.

The effects were cumulative, and for children who swam the most frequently, equivalent to the damage found in the lungs of regular smokers, say the authors.

The immediacy of the damage done was evident in the levels of the marker proteins, which were significantly higher after just one hour spent at the poolside, without swimming.

An increase in IgE, a risk factor for asthma, was not associated with regular swimming itself, but was linked to an increase in the smaller of the proteins indicative of lung damage (SP-B). Furthermore, chest tightness after exercise, and overall prevalence of asthma, were both linked to the cumulative amount of time spent at indoor pools.

The effects were the same for children wherever they lived, and remained after taking account of other environmental pollutants. But they were strongest in the youngest children.

The authors point out that swimming is recommended for asthmatics because the hot humid air in pools compensates for the effects of exercise, but not if the air is laden with toxins. Levels of trichloramine can vary greatly, depending on how crowded a pool is, how clean the swimmers are, and how well ventilated the area is.

The authors conclude that chlorinated indoor swimming pools might explain the rise in diagnoses of childhood asthma. "The question needs to be raised as to whether it would not be prudent in the future to move towards non-chlorine based disinfectants, or at least to reinforce water and air quality control in indoor pools…in order to minimise exposure to these reactive chemicals," they add.

Bronchospasm in competative swimmers

Reuters Health, March 21, 2001.

A study presented [03/20/2001] in New Orleans at the 57th Annual Meeting of the American Academy of Allergy, Asthma and Immunology, strongly suggested that swimming pool environments adversely affect the lung function of competitive swimmers. Dr. Stephen J. McGeady, and colleagues, from Thomas Jefferson University in Wilmington, Delaware, measured the lung function (FEV1) of competitive swimmers (N = 28) before and after cycle ergometer testing in swimming pool and laboratory settings. The study was motivated by observations of university team swimmers displaying significant airway obstruction and the number of reports that many swimmers use beta-agonist inhalers.

Ss' mean FEV1 was significantly lower in the pool than in the laboratory. Some swimmers (14%), not previously asthmatic, displayed airway obstruction at baseline. Exercise-induced bronchospasm occurred in a further 11% of swimmers not known to have that problem or asthma. Swimmers known to have asthma seemed to do better than swimmers who were not diagnosed with asthma. Exercise-induced bronchospasm negatively affected performance.

Implications. Swimming is worse on bronchospasm than other endurance sports, a paradox since swimming is supposed to promote health. The facility/exercise setting is implicated as the cause of these respiratory afflictions. Because of swimming pool environments, competitive swimming could be bad for one's health!

[Thanks to Johnny Morton, former collegiate swimmer, current parent, official, coach and interested observer, for bringing this to my attention -- BSR]

ADDITIONAL REFERENCES

1. Beech, J.A., Diaz, R., Ordaz, C., & Palomeque, B. (1980). Nitrates, chlorates and trihalomethanes in swimming pool water. American Journal of Public Health, 70(1), 79-82.

Water from swimming pools in the Miami area was analyzed for nitrates, chlorates and trihalomethanes. The average concentrations of nitrate and chlorate found in freshwater pools were 8.6 mg/liter and 16 mg/liter respectively, with the highest concentrations being 54.9 mg/liter and 124 mg/liter, respectively. The average concentration of total trihalomethanes found in freshwater pools was 125 micrograms/liter (mainly chloroform) and in saline pools was 657 micrograms/liter (mainly bromoform); the highest concentration was 430 micrograms/liter (freshwater) and 1287 micrograms/liter (saltwater). The possible public health significance of these results is briefly discussed.

2. Mustchin, C.P., & Pickering, C.A. (1979). "Coughing water": bronchial hyper-reactivity induced by swimming in a chlorinated pool. Thorax, 34(5), 682-683.

3. Decker, W.J., & Koch, H.F. (1978). Chlorine poisoning at the swimming pool: an overlooked hazard. Clinical Toxicology, 13(3), 377-381.

Discussion Points

Governmental regulation agencies have standards for PASSIVE air in enclosed swimming pools. At least that was the case the Carlile Organization experienced at Narrabeen several years ago when many of its top swimmers were ill. The supervising staff did all the environmental testing and the air was deemed to be safe and within published guidelines. Even after the declaration that the air was "good" swimmers remained ill particularly with upper respiratory problems.

However, according to the above research an exercising athlete increases the toxicity of the chlorinated pool atmosphere by 700%! That should be a high-level health risk! Safety accrediting agencies need to upgrade their standards to be reflected in active alveolar air, not passive environmental air.

People in swimming over the past decade have become alarmed at the high proportion of training swimmers who are diagnosed/treated asthmatics. However, "swimming asthma" might well be hypersensitivity to chloroform and the other gases as explained in the abstract and not truly asthma.

Is it possible that our sport might be generating life-long health problems purely because of the environment in which swimmers are continually exercised? If that is so there is a MAJOR PROBLEM WITH OUR SPORT.

I would appreciate hearing of any learned writings or investigations on this matter.

mailto:brushall@mail.sdsu.edu

Chlorine product absorption in swimmers is greatest via the skin

Lindstrom, A.B., Pleil, J.D., & Berkoff, D.C. (1997). Alveolar breath sampling and analysis to assess trihalomethane exposures during competitive swimming training. Environmental Health Perspectives, 105(6), 636-642

Alveolar breath sampling was used to assess trihalomethane (THM) exposures encountered by collegiate swimmers during a typical 2-hr training period in an indoor natatorium.

Breath samples were collected at regular intervals before, during, and for three hours after a moderately intense training session. Integrated and grab whole-air samples were collected during the training period to help determine inhalation exposures, and pool water samples were collected to help assess dermal exposures.

Resulting breath samples collected during the workout demonstrated a rapid uptake of two THMs (chloroform and bromodichloromethane), with chloroform concentrations exceeding the natatorium air levels within eight minutes after the exposure began. Chloroform levels continued to rise steeply until they were more than two times the indoor levels, providing evidence that the dermal route of exposure was relatively rapid and ultimately more important than the inhalation route in this training scenario. Chloroform elimination after the exposure period was fitted to a three compartment model that allowed estimation of compartmental half-lives, resulting minimum blood borne dose, and an approximation of the duration of elevated body burdens. It was estimated that dermal exposure route accounted for 80% of the blood chloroform concentration and the transdermal diffusion efficiency from the water to the blood was in excess of 2%. Bromodichloromethane elimination was fitted to a two compartment model that provided evidence of a small, but measurable, body burden of this THM resulting from vigorous swim training.

These results suggest that trihalomethane exposures for competitive swimmers under prolonged, high-effort training are common and possibly higher than was previously thought and that the dermal exposure route is dominant. The exposures and potential risks associated with this common recreational activity should be more thoroughly investigated.

Implication. In this study the greater importance of transdermal (via the skin) uptake of chlorinated hydrocarbons compared to the respiratory route is demonstrated. This indicates that improved ventilation alone will not have a major impact on exposure to these materials because it is being immersed in the liquid that is the greatest threat. In contrast, ozonation allows markedly reduced levels of chlorine in the pool water.

Exercising Increases the toxicity of a " safe" chlorinated pool atmosphere

Drobnic, F., Freixa, A., Casan, P., Sanchis, J., & Guardino, X. (1996). Assessment of chlorine exposure in swimmers during training. Medicine and Science in Sports and Exercise, 28(2), 271-274.

The presence of a high prevalence of bronchial hyper responsiveness and asthma-like symptoms in swimmers has been recently reported. Chlorine, a strong oxidizing agent, is an important toxic gas that a swimmer can breath in during training in chlorinated pools.

Measurements of the chlorine concentration in the breathing zone above the water (< 10 cm) were obtained randomly during five non-consecutive days in four different swimming pool enclosures. The mean level in all the swimming pools was 0.42 +/- 0.24 mg/m3, far below the threshold limited value (TLV) of 1.45 mg/m3 for the work places for a day of work (8 h). The TLV could be reached and even exceeded if we consider the total amount of chlorine that a swimmer inhales in a daily training session of two hours (4-6 g) compared with a worker during eight hours at the TLV (4-7 g). Low correlation was observed with the number of swimmers in the swimming pool during the measurements (0.446) and other variables as the water surface area of the pool, volume of the enclosure, and the chlorine-addition system in the swimming pool. A low turnover rate in the air with an increase of chlorine levels through the day was observed in all pools.

The concentration of chlorine in the microenvironment where the swimmer is breathing is below the TLV concentration limit, but nevertheless results in a high total volume of chlorine inhaled by the swimmers in a given practice session.

The possible role of chlorine in producing respiratory symptoms in swimmers needs further investigation.

Implication. Even though chlorine concentrations in a pool environment are at acceptable "safe" levels, it is a swimmer's exercising that produces abnormal levels of exposure to this toxin.

There has not been sufficient research to even begin understanding the health effects of this repetitive exposure.

Amount of exercise is related to chlorine-related concentrations In the body

Cammann, K., & Hubner, K. (1995). Trihalomethane concentrations in swimmers' and bath attendants' blood and urine after swimming or working in indoor swimming pools. Archives of Environmental Health, 50(1), 61-65

The influence of working or swimming in indoor swimming pools on the concentrations of four trihalomethanes (haloforms) in blood and urine was investigated. Different groups (bath attendants, agonistic swimmers, normal swimmers, sampling person) were compared.

The proportions of trihalomethanes in blood and urine correlated roughly with those in water and ambient air. Higher levels of physical activity were correlated with higher concentrations. Within one night after exposure in the pool the blood concentrations usually were reduced to the pre-exposure values. Secretion of trichloromethane in urine was found to be less than 10%.

Implication. Exercising in a chlorinated pool increases the levels of assimilation of chlorine related gases. The greater the amount of exercise, the greater the concentrations. Thus, hard training swimmers are at greater risk than more sedentary pool attendants and coaches.

It takes at least one night for absorbed substances to be removed. If insufficient time exists between training sessions the possibility of toxic build-up is real.

Young swimmers at greatest health risk In chlorinated Indoor pools

Aiking, H., van Acker, M.B., Scholten, R.J., Feenstra, J.F., & Valkenburg, H.A. (1994). Swimming pool chlorination: a health hazard? Toxicology Letters, 72(1-3), 375-380.

A pilot study addressed potential effects of long-term exposure to chlorination products in swimming pools.

The indicator compound chloroform was detectable in blood from competitive swimmers in an indoor pool (mean = 0.89 +/- 0.34 microgram/l; N = 10), but not in outdoor pool swimmers. No hepatotoxic effect was indicated by serum glutamate oxaloacetate transaminase (SGOT), serum glutamate pyruvate transaminase (SGPT) or gamma-glutamyl transpeptidase (gamma-GT) enzyme levels. beta-2-microglobulin, an indicator of renal damage, was significantly elevated in urine samples of the slightly, but significantly, younger indoor swimmers.

The precise ratio between these two possible causes, age and chloroform exposure, as well as the mechanism of the former, remain to be elucidated.

Implication. The toxic effects of chlorine products in swimmers training in indoor pools are greater in younger than older swimmers. Young swimmers are therefore at a greater health risk.

Chlorinated tablets pose health risk

Wood, B.R., Colombo, J.L., Benson, B.E. (1987). Chlorine inhalation toxicity from vapors generated by swimming pool chlorinator tablets. Pediatrics, 79(3), 427-430.

The authors presented two cases of serious respiratory injury after brief exposure to vapors from solid chlorine compounds. No previous reports of such accidents were located and, therefore, this paper related these cases to alert the medical community. It was recommend that physicians caring for children include warnings about these preparations in their routine counseling of parents.

Implication. Chlorinator tablets are of such a concentration that acute exposure to them is hazardous.

Dental enamel erosion Increased In competative swi„ers In chlorinated pools

Centerwall, B.S., Armstrong, C.W., Funkhouser, L.S., & Elzay, R.P. (1986). Erosion of dental enamel among competitive swimmers at a gas-chlorinated swimming pool. American Journal of Epidemiology, 123(4), 641-647.

In September 1982, two Charlottesville, Virginia, residents were found by their dentists to have general erosion of dental enamel consistent with exposure to acid. Both patients were competitive swimmers at the same private club pool. No other common exposure could be determined. An epidemiologic survey was made of 747 club members.

Symptoms compatible with dental enamel erosion were reported by 3% of non-swimmers (9/295), 12% of swimmers who were not members of the swim team (46/393), and 39% of swim team members (23/59). All four swimmers with clinically verified dental enamel erosion had trained regularly in a particular pool. That pool was compared to one that had eight equivalent swimmers without enamel erosion. Examination of the implicated swimming pool revealed a gas-chlorinated pool with corrosion of metal fixtures and etching of cement exposed to the pool water. A pool water sample had a pH of 2.7, i.e., an acid concentration approximately 100,000 times that recommended for swimming pools (pH 7.2-8.0). A review of pool management practices revealed inadequate monitoring of pool water pH.

Acid erosion of dental enamel -- "swimmer's erosion" -- is a painful, costly, irreversible condition which can be caused by inadequately maintained gas-chlorinated swimming pools.

Implication. Overchlorinated pools that produce excessively elevated levels of acidity can contribute to dental enamel erosion in competitive swimmers. Individuals who frequent pools less are less likely to be threatened.

AMERICAN JOURNAL OF PUBLIC HEALTH - Dr.Halina Brown
"Showering is suspected as the primary cause of elevated levels of chloroform in nearly every home because of the chlorine in the water."

SCIENCE NEWS, VOL. 130 - Janet Raloff
"The cause of atherosclerosis and resulting heart attacks and strokes is none other than the ubiquitous chlorine in our drinking water."

CHEMISTRY AND CONTROL OF MODERN CHLORINATION - Dr. A.T. Palin, Ph.D..(O.B.E.)
"Chlorine gas was despicably used during WWI. When the war was over, the use of chlorine was diverted to poisoning germs in our drinking water. All water supplies throughout the country were chlorinated. The combination of chlorine (when in drinking water) and animal fats results in atherosclerosis, heart attacks, and death."

THE WASHINGTON POST
"The EPA has raised skin absorption of chlorine to its top 10 carcinogen watch list."
June 1994

UK: April 5, 2002

LONDON - Scientists warned yesterday that high levels of a chemical compound found in indoor swimming pools might pose a risk to pregnant women and their unborn babies.

Researchers at Imperial College London said they found levels of trihalomethanes (THMs), a by-product of chlorine, in London swimming pools that were higher than amounts found in tap water which had been associated with health problems.

"There have been some previous studies carried out with tap water where they found some effects like spontaneous abortion, stillbirths and congenital malformations at lower levels of these byproducts," said Dr Mark Nieuwenhuijsen, who led the study reported in Occupational and Environmental Medicine.

He added that the by-product levels are relatively high but scientists do not know what effects THMs in swimming pools might have on pregnant women and unborn babies.

THMs are formed when chlorine, which is added to swimming pools to keep them clean, reacts with organic matter such as skin or hair.

Nieuwenhuijsen said more information is needed about THMs, which can be swallowed or inhaled, and their impact on pregnant women. In the meantime efforts should be made to reduce the levels, he said.

"The owners of swimming pools have to make sure they reduce the by-product levels because there might be a risk if they stay at this level," Nieuwenhuijsen said.

Chlorine is necessary to disinfectant swimming pools but the scientists said levels of THMs can be reduced by making sure people clean themselves before swimming. Filtering the water can also help to keep organic matter at low levels.

The scientists examined 44 water samples from eight indoor pools in London and compared the levels of THMs found in the pools and in tap water. Although the amount of THMs varied according to the water temperature and the number of people in the pool, it was higher than levels found in tap water.

REUTERS NEWS SERVICE

Dual or Multistage Sanitation Systems

Chapter three : Dual or Multi Stage Sanitation Systems

There is a lot of evidence based on world wide experience and studies, that when two or more sanitation techniques combined, the result is better than if any one system used on its own.

This is called Dual or multistage sanitation.
The benefits are:
Better quality water since pathogens have varied sensitivity against different biocides.
More reliable system
Cheaper to run in most cases
Higher swimmer satisfaction
Less side effects from sanitation by-products
Lower chlorine use

Below we enclose a number of international studies and papers on the efficacy on Dual or Multistage sanitation.

A report on the advantages of using a dual stage method of sanitation

The University of Arizona and a certified independent lab, both recently demonstrated that even 0.10 ppm of chlorine is very effective in treating a pool when there are copper and silver ions present in the pool.1

It is not a question of whether using copper and silver or using chlorine is the better way to keep a swimming pool sanitized and algae free. A good case can be made for either methods. Studies have shown that an ideal method is to use a combination of all three elements.2

G.R. Taylor, at Surrey University, proposed a dual disinfection method after his tests showed that:

"Two different chemicals of metals added together may allow more efficient disinfection kinetics to be achieved. One substance targets the surface of a micro-organism killing and injuring the cells while a second substance targets the nucleic acid of the micro-organism destroying the remaining injured micro-organisms. By using this method of dual disinfection, reduced levels of both substances may be more effective than much higher levels of either individual substance."3

The major advantages of this dual, or two stage disinfection method, are as follows:

Superior sanitation to any single method alone Reduced testing and maintenance Conforms with all health department regulations for public pools A demonstrated cost savings can be achieved Following is a brief of some important facts and test data on each of the three swimming pool disinfection methods.

The Copper-Silver System

A common and very effective method of purifying swimming pools is to use electronically produced copper and silver ions. It was previously promoted that copper was a more effective algaecide and silver the more effective bactericide. More recent studies have shown each to be highly effective in the control and killing of both bacteria and algae. Together they give superior results. Copper has the ability to pierce the protective outer membrane of a cell and disrupt enzyme balance. Silver is effective because of its capabilities of interfering with DNA production and accelerating the death phase. This method has the advantage over chlorine of remaining very stable in swimming pools. The pool will stay sanitized for days or weeks with the system turned off and no additional copper or silver being added.

Copper and silver are not absorbed through the skin and, therefore, are not carried out of the pool by swimmers. They are also not affected by sunlight and actually become slightly more effective as the water is heated or the pH increases.

Copper and silver are safe. At the normal recommended levels of copper in a swimming pool, a person would have to drink over two gallons of pool water just to get the amount of copper in one vitamin pill. A glass of EPA approved tap water could have five times as much copper in it as a glass of swimming pool water. The tap water could also have five times as much silver as a glass of pool water.

The Environmental Protection Agency completely removed any limits on silver in drinking water in 1989 because they said it presented no hazard to human health.

A multitude of tests have shown the effectiveness of copper and silver in killing E. Coli bacteria. Many other tests have shown that silver also kills viruses and other types of bacteria. Coleman reported that herpes simplex virus (HSV) type I was quite sensitive to silver.4 Richards reported that only 3 ug/1 silver was necessary to prevent the growth of pseudomonas.5 Moroz reported that silver kills salmonella and E. Coli and can kill bacteria highly resistant to antibiotics.6

The Allegheny County Pennsylvania Health Department conducted a test on a 152,000 gallon public pool for an entire season. The average bather load was 200 people per day. The only disinfectant used was 20 ppb of silver. The health department found the water totally free of coliform, pseudomonas and staphylococcus bacteria throughout the season, whereas 65 water samples from 30 other chlorine treated swimming pools in Allegheny County, having a mean concentration of 0.70 ppm of chlorine, did routinely show the presence of bacteria.

The Silver Institute , Washington, D.C., issued a report showing that a 20,000 gallon pool in Lincoln, Nebraska, infused with 50 gallons of sewer effluent was purified to a zero level with only 3.2 ppb of silver in the water as the disinfectant.7

Dr. Charles Gerba at the University of Arizona in Tucson reported recently that legionella pneumophila (which causes the lethal legionnaire's disease and which can be present in swimming pools) was killed approximately 100 times faster when the system was used to add 0.20 ppm of copper and 20 ppb of silver to 0.20 ppm of chlorine as compared to the use of chlorine itself. Legionella is very resistant to even higher levels of chlorine.

Tests performed by Dr. Friede at Villanova University showed that in swimming pool water containing ammonia (a typical swimming pool condition) silver was a much faster and more effective sanitizer than chlorine.

Eighty minutes was required for a virtually complete kill of pseudomonas aeruginosa bacteria using chlorine versus only twenty minutes using silver. Likewise, silver took only one minute for a 70% kill compared to ten minutes for chlorine.

The Conventional Chlorine System

Chlorine is a good disinfectant under certain conditions, but when the pH becomes a little high, a common problem with most pools, chlorine becomes almost totally ineffective. For example, when the pH is 8.0 the chlorine is only 20% effective and at a pH of 8.5 the chlorine is only 8% effective.

Another problem with chlorine is the difficulty of maintaining a residual in the generally accepted range of 1.0 to 3.0 ppm. Chlorine is dissipated rapidly by sunlight. It is also absorbed through the skin. The effective chlorine in a pool can be almost totally depleted in a few hours. This can happen even when a automatic chlorinating system is used.

Dr. Peter Gaffney, Professor of Microbiology at Georgia State University, in a study "Microbiological Evaluation of Swimming Pools in Fulton County Georgia (Atlanta)" reported that out of 282 pools tested, 55% had a chlorine level of less than 0.5 ppm. He also reported that over 50% of the pools which had a chlorine level above 2.0 ppm still had both E. Coli and Pseudomonas bacteria present.

This indicates that a large percentage of pools do not always maintain a sufficient level of chlorine and even in those that do, a large percentage are still not safe for swimming.

The results of an independent test of commercial spas being treated with chlorine in Portland, Oregon, were reported in "Swimming Pool Age &Spa Magazine" in November 1985. The report showed that 28 out of 30 (93%) of the spas tested did not meet health department standards.

In 1985, USA Today reported " Swimmers had significantly more eye, ear and skin infections than non-swimmers, largely because of high bacteria and virus levels in pools, according to Illinois Public Health Researcher, Linda Berrafato." If the conventional chlorine method was working, swimmers would not have significantly more infections than non swimmers. What all of these tests are showing is that chlorine by itself is not doing a satisfactory job of protecting the health of swimmers.

Dual Disinfection Method

The new dual or two stage disinfection method is an answer to the deficiency associated with chlorine. The dual method provides excellent results without relying on the sometimes unattainable, near perfect water conditions required for satisfactory results.

By using the dual disinfection method of Taylor, at Surrey University, Thurman and Gerba at the University of Arizona have demonstrated that copper and chlorine do function as dual disinfectants as shown in the graph.

This graph shows that even in a minute, 0.10 ppm of chlorine plus copper was very effective whereas this amount of chlorine by itself as totally ineffective. In another test conducted by

The George Washington University Medical School, the combination of silver and chlorine showed an even faster kill rate than copper and chlorine did. Their results on E. Coli bacteria showed that even 0.05 ppm of chlorine and 40 ppb of silver killed 100% of E. Coli bacteria in only 15 seconds. Chlorine by itself will not do this even at much higher levels.

The test data from several independent sources clearly demonstrates that using a combination of copper, silver, and chlorine as a disinfectant and algaecide in swimming pools will do a better job of insuring the health of swimmers with no increased risk because of the following:

A residual level of chlorine is still maintained in the pool and this in itself does provide some level of protection (good, but not always adequate). The copper and silver is a disinfectant that would be very effective even without chlorine. They are not adversely affected by sunlight, high pH or high temperatures the way chlorine is. The dual disinfectant benefits will be available as long as there is even a trace of chlorine left in the pool, as shown previously. This allows a considerable margin of error in maintaining a pool. Any system that does not allow for this margin of error is not going to produce satisfactory results.

Conclusions

Numerous tests conducted by many certified independent labs and universities demonstrate that a combination of copper, silver, and chlorine is much more effective than chlorine alone.

The scientific facts available conclude that a combination of chlorine plus the copper and silver system is a proven, safe and economical approach to purifying water in swimming pools and spas. The new dual disinfection method is also easy to implement in public and commercial pools because there are usually no laws or regulations that need to be changed

REFERENCES

1.Thurman, R. and Gerba, C., The Molecular Mechanisms of Copper and Silver Ion Disinfection of Bacteria and Viruses, University of Arizona, Tucson, 1988.

2.Gerba, C. and Kutz, S., Microbiological Evaluation of Free Chlorine and Copper: Silver Ions against Pseudomonas Aeruginosa and Legionella Pneumophila, Department of Microbiology and Immunology, University of Arizona, Tucson, 1988.

3.Taylor, G.R., The Effect of Disinfectants on Picornavirus Structure and Ineffectivity, in Viruses and Disinfection of Water and Wastewater,

4.University Surrey, Guilford, Surrey, 1982. Coleman, V.R., Wilkie, J., Levinson, W.E. Stevens, T., and Jawetz, E., Inactivation of Herpes Virus hominis Types 1 and 2 by Silver Nitrate in vitro and vivo, Antimicrobial Agents and Chemother., 4, 259, 1973.

5.Richards, R.M.E., Antimicrobial Action of Silver Nitrate, Microbios, 31, 83, 1981.

6.Moroz, O.G., Kulskii, L.A., Prokuryakova, N.B., Rudenko, A.V., and Florensova, K.M., Susceptibility of Organisms which cause Intestinal Infections to Removal by Silver, Khimiya; Tecknologiya Vody., 2, 275, 1980.

7.The Silver Institute, Washington, D.C.

Efficacy of Copper/Silver Ion Generation with Reduced Chlorine Concentrations on Disinfection and Operation of a Municipal Swimming Pool.

ABSTRACT

The disinfection of swimming pool water in the Town of Brookline, Massachusetts' Municipal Swimming Pool Recreational Facility using chlorine concentrations according to the provisions of Chapter V of the Massachusetts Sanitary code (1.0 ppm free available chlorine) is compared with the use of Copper/Silver ion generation with the use of low levels of free available chlorine (0.4 ppm). Comparisons are made usin5 standard methods for the detection of coliform bacteria and heterotrophic bacteria using the standard plate count method. In addition, comparisons are made relative to trihalomethane production (THM) under conditions of chlorine disinfection alone and copper/silver ion.

I. Bathing Water Microorganisms and Traditional Disinfection Techniques

Microorganisms, including bacteria, protozoa and viruses occur naturally in recreational waters. Some of these microorganisms can be pathogenic, i.e., capable of causing human disease, and are, therefore, of legitimate public health concern. In swimming pools, these microorganisms may be introduced into the water by "carriers" and transmitted to other bathers via mechanisms of ingestion, inhalation, or broken skin. The literature is rife with instances of disease transmission involving the use of recreational waters (1).

Proper treatment of swimming pool water is essential to protection of the public health from diseases spread by microorganisms as discussed above. Swimming pool water treatment methodologies have traditionally incorporated the agglomeration of microorganisms and other water impurities utilizing chemicals such as aluminum sulfate and subsequent filtration through a medium such as sand or diatomaceous earth. However, due to a variety of reasons, including but not limited to the wide variation in size of microorganisms, the efficiency of the agglomeration technique and break-through in the filter medium, this treatment technology cannot be solely relied upon for water purification purposes. Effective disinfection of properly treated swimming pool waters has traditionally been accomplished by the addition of chlorine and chlorine compounds (2)(3)(4). In larger pools, chlorine is normally dispensed through a calibrated flow meter as gaseous chlorine or in aqueous solution as sodium hypochlorite, while in smaller residential pools, chlorine is dispensed as solid calcium hypochlorite. In all cases the active disinfecting agent is with low chlorine levels. Finally, the results of bather satisfaction using a bather survey technique are discussed under conditions of each test protocol. hypochlorous acid (HOCL). To insure effective elimination of all pathogenic microorganisms and to provide excellent general sanitary quality of swimming pool waters, State Health and/or Environmental regulatory agencies require that the bathing water contain an excess amount of free available chorine (FAC) above the amount which enters into reactions designed to inhibit the activity of microorganisms. In Massachusetts, swimming pool operators are currently required to maintain FAC levels of 1.0 ppm at all times when a pool is in use.

II. Disinfection Using Copper/Silver Ion Generation

The use of metallic ions in water disinfection techniques is not new. The early Greeks used copper and silver goblets and vessels for drinking and storage purposes (5). The low solubility of these metals served as a natural, controlled release mechanism which added trace amounts of these ions to the water. Such amounts were high enough to purify the liquid without causing objectionable taste.

More recent use of copper and silver ions to inactivate microorganisms is well documented (6)(7)(8)(9). In addition to bacteria, they also are effective in controlling viruses, algae and fungi in the part per billion (ppb) range. Copper and silver ion disinfection of swimming pool water has several advantages over chlorine, viz., the ions are chemically stable and do not undergo the destructive reactions of aqueous chlorine; they do not form objectionable by-products such as chloramine or Trihalomethanes (THM); they do not escape from the water by volatilization as chlorine does.

Maintaining ppm range concentrations of copper and silver ions in swimming pool water in a convenient and reproducible manner is accomplished by electrolytic generation of the ions. electrolytic ion generators consist of a positively charged anode consisting of the metals to be ionized and a negatively charged cathode. The electrodes are housed in a chamber through which the water to be purified flows. The anode and the cathode are connected to a power source and a weak electrical charge flows between them, releasing silver and copper ions from the anode. The metals ion concentration is precisely controlled by varying both the flow rate of water through the chamber and the current to the electrodes.

Experimentation and publication by Gerba and others (10)(11)(12)(13)(14) indicates that 300-400 ppb of copper and 40 ppb silver combined with 0.1 ppm -0.4 ppm of chlorine is more effective in controlling a host of microorganisms, including coliform, than the use of higher levels of chlorine. The research points toward a synergistic effect when water containing microorganisms is subjected to copper/silver ion treatment with low levels of chlorine.

III. Test Protocol

The Town of Brookline Municipal Swimming Pool was chosen as the site for the current study because it is well maintained and operated by the Recreation Department staff is well regulated by the Brookline Health Department staff and it is utilized year round by the citizens of the Town and the surrounding community and organized high school swimming programs.

Chapter V of the Massachusetts Sanitary Code requires swimming pool waters to be disinfected using chlorine at a rate resulting in a FAC of 1.0 ppm. The Code also allows for alternative treatment technologies, but, at present, since they are viewed only as supplementary disinfectants, they must still conform with the above chlorine standards. If an operator wishes to operate below this minimum FAC requirement, then that is handled as a matter of variance issued by the local Board of Health after a public hearing and subsequent approval of that variance by the Massachusetts Department of Public Health (MDPH).

The Brookline Recreation Department applied to the Brookline Commissioner of Public Health on February 20,1996, for a variance to conduct a ten (10) week study using copper/silver ionization with reduced chlorine levels. On March 5,1996, a public hearing was held and on March 21,1996 the Brookline Health Department issued a variance for test purposes. On March 27,1996 the MDPH approved the variance. .

Under terms of the issued and approved variance, the test was to be carried out under a protocol which is attached to this report (Appendix n. The protocol in summary required Crystal Water Systems to conduct a two (2) week `Baseline Period" study whereby physical, chemical and bacteriological data and samples would be gathered for analysis by a certified laboratory (G&L Labs of Quincy, Ma.). During this period, no changes would be made relative to pool operation, i.e. chlorine dosage would remain such that a 1.0 ppm FAC was maintained.

At the end of the `Baseline Period", the installed copper/silver generator would be activated. When the copper levels in the pool water reached 300 ppb, chlorine levels would be reduced to 0.4 ppm. The facility would then be operated in this manner for a period of eight (8) weeks, during which data gathering, sampling and analyses would be intense.

An integral part of the test protocol was the design and implementation of a consumer reaction questionnaire which is attached (Appendix II).

IV. Purpose of the Test

The test, under the protocol described, was carried out to determine whether copper/silver ion generation used in conjunction with substantial reduction in chlorine usage, provides the same or better public health protection as the use of high levels of chlorine alone. The test was also designed to determine if the use of lower levels of chlorine have any positive effects on bather satisfaction.

V. The Swimming Pool

The Brookline Municipal Swimming Pool was constructed in 1958. Three distinct areas comprise the total pool complex viz., the diving area the wading area, and the lap pool. The three pools have a total volume of 245, 880 gallons.

Water supply for the pools is obtained from the Town of Brookline municipal water supply system which obtains its water from the Massachusetts Water Resources Authority (MWRA), a regional water supplier for the entire metropolitan Boston area. MWRA water is obtained totally from surface supplies, is not presently filtered, and is treated only with chlorine for disinfection, soda ash for corrosion control and sodium fluoride for control of dental caries. The Brookline municipal pool water is filtered through enclosed low pressure sand filters having a total capacity of 520 gallons per minute (gpm). The entire content of the pools are, therefore, filtered every eight hours.

Sodium hypochlorite in 10% aqueous solutions used for the disinfection purposes. It is fed through an electrically operated pump calibrated to maintain a FAC level in the pool water of not less than 1.0 ppm. Average chlorine usage is 9-10 gallons per day, providing an average chlorine dosage of 1.8 ppm. when chlorine alone is used for disinfection purposes. During the Pilot Phase of the study after introduction of copper/silver ions at the desired level, chlorine usage was reduced to less than 3 gallons per day 2.67g.p.d.)

VI. The Cooper/Silver Generator

The copper/silver ion generator is a Water System Model CWS 3001. The unit is NSF approved per Standard 50-1992 and UL listed. The system consists of two components: a controller and two flow cells which contain six copper/silver electrodes each. The controller measures 19 ½" x 15 ¾" x 8 3/8" and weighs 25 lbs. Input power to the controller is 110/220 volts 50/60 hertz; while Output is 16 volts Max 10 amps. It is a Class 2 Transformer. The Flow cells are constructed of high pressure Schedule 80 PVC and measure 18" long. The ratio of copper/silver is 99:1, respectively. This ratio allows the copper/silver ions imparted into the pool to fall within EPA Drinking Water Regulations which is a NSF requirement. The System was installed on July 18,1996. The electrodes were inserted as an offset to a separate water loop fed off the main pool line that feeds the Dectron dehumidifier on the roof.

VII. Baseline Period Testing

On June 25,1996 baseline data relative to chlorine residual (FAC), coliform bacteria total heterotrophic plate count and trihalomethane (THM) began to be gathered and continued until July 3l, 1996 - a period of 5.5 weeks. This represents an almost three-fold increase in data relative to the test design protocol, but was thought to be prudent considering that a FAC concentrations ranged from a minimum of 0.3 ppm to 3.10 ppm.

Review of the data indicates that as expected coliform bacteria appeared to be well controlled with only a single sample showing one (1) coliform colony at a time when average FAC was 1.9 ppm.

Relative to heterotrophic bacteria, an average of 90.8 colonies/ml were determined during this period.

An average concentration of 121.2 micrograms per liter (ug/L) of trihalomethanes was detected during the Baseline Period.

Bather load was on average of 288 persons/day during the Baseline Period.

VIII. Ionizer Ramp UP Period

From August l, 1996 through September 16,1996, the copper/silver ion generator was introduced into the water treatment system, while chlorine dosage levels were reduced. The ion generator responded well to ramp-up, reaching a level of 0.3 ppm by August 17,1996, the pool was fully ionized. However since the pool was to be closed (August 25,1996 - September 10, 1996) for its annual maintenance program, the Pilot Phase part of the test was delayed until the reopening. Following the reopening of the pool and restoring the copper levels (see (1) below), The chlorine levels were reduced to the 0.4 ppm level as stipulated in the protocol and the Pilot Phase commenced.

IX. Pilot Test Periods

On September 17,1996, data began to be gathered relative to the actual performance of copper/silver ionization with reduced levels of chlorine and continued for an uninterrupted period of four weeks. During the period from October 19,1996 through October 23,1996, the Boston area received almost nine (9) inches of rainfall causing severe generalized flooding conditions throughout the area. The Brookline Municipal Pool Building was a victim of this flooding and the swimming pool water treatment room was inundated causing failure of all pumps. The pool, with ionizer fully operational, and copper levels restored to 0.3 ppm was not in operation until November 1l, 1996.

Upon restoration of all pool equipment, the Pilot Period was once again commenced on November 11 , 1996, and ran uninterrupted until December 21,1996, a period of six weeks. Pilot test period in the aggregate provide ten weeks of data.

During this time period FAC levels averaged 0.52 ppm with an occasional excursion to 1.0 ppmbut for the most part remained in the 0.4 - 0.5 ppm range.

Copper/silver ion levels remained consistent at the 0.3 ppm level with only occasional readings of 0.2- 0.25 ppm.

No coliform bacteria colonies were developed throughout the Pilot Period Test. Relative to heterotrophs, an average of 20.2 colonies were counted during this period. 48.5 ug/L of THM was detected as an average during the test period. Bather load during this period averaged 202 persons/day.

X. Discussion

A) Free Residual Chlorine (FAC)
It is interesting to note the extremes in chlorine concentrations during the Baseline Period data collection. Chlorine concentrations ranged from a maximum level of 3.10 ppm to a minimum of 0.3 ppm. The average maximum level was 2.7 ppm and the average minimum level was 0.6 ppm which is a spread of 4.5 times. This spread indicates two things: i) the chlorine residual is unstable and is quickly subject to the influence of chlorine demand (bather load); and ü) the chlorine feed system either reacts slowly to changes in chlorine residual or that high/low set point signals are set too widely apart.

Data collected during the Pilot Period demonstrated chlorine concentrations ranging form a maximum level of 1.3 ppm to a minimum of 0.2 ppm. The average maximum level was 1.0 ppm and the average minimum level was 0.4 ppm, which is a spread of only 2.5 times. This suggests that the chlorine residual was more stable when copper/silver ions were being used.

B) Coliform Bacteria
Coliform bacteria levels appeared to be well controlled throughout the duration of the study whether using conventional high levels of chlorine alone or when using copper/silver ions in conjunction with reduced levels of chlorine. The only coliform event detected during the study occurred during the Baseline Period data collection when chlorine levels were at an average of 1.9 ppm FAC.

C) Heterotrophic Plate Count
The heterotrophic plate count data provide the most significant information regarding the capabilities of the two disinfection strategies. This data provides a measure of the total heterotrophic bacteria in the pool water. It looks at a much larger population of bacteria than the important but more limited group of organisms detected in the coliform procedure. Therefore, the heterotrophic plate count provides a better measure of the overall sanitary condition of the pool water.

The Pilot Period study showed far lower numbers of heterotrophic bacteria detected than during the Baseline Period data collection. An average of 90.8 colonies/ml were found in samples collected during the Baseline Period, while only 20.2 colonies/ml were detected while using copper/silver ionization. This represents a 78% reduction in bacterial population.

D) Trihalomethanes (THM)
Trihalomethanes (THM) are a group of halogenated hydrocarbons which have been found to be potentially cancer causing. THM are produced when chlorine is introduced into water containing organic constituents and can either be ingested or absorbed through the skin. Therefore, THM concentrations in drinking water are regulated by the United States Environmental Protection Agency (LTSEPA) at a level of 100 ug/ml. There is no regulated maximum concentration for THMs in swimming pools.

An average concentration of I21.2 ug/L was found in samples collected during the Baseline Period, while an average concentration of only 48.5 ug/L was found during the Pilot Period of the study. This represents a 150% reduction in THM concentrations.

XI. User Satisfaction

In order to gain insight into whether the introduction of copper/silver ions with reduced levels of chlorine has any effect on the bathing experience of users of the swimming pool, a survey was designed, implemented and analyzed by Opinion Dynamics of Cambridge, Ma. The full report is attached (Appendix II].

It is well understood that bathers who use swimming pools using chlorine alone as a disinfectant have experienced a variety of unpleasant side effects, including but not limited to, bleaching of skin, hair and bathing suit material; eye, nose and throat mucous membrane irritation; unpleasant odors; and skin irritation and rashes. Such pool users seem to understand that these unpleasant effects are the price to be paid for assurance that the pool water is free from parthenogenic organisms. In fact, some persons are so sensitive to chlorine as to cause them to avoid using swimming pools.

The survey found a marked increase in bather satisfaction swimming in water disinfected by copper/silver ions and low levels of chlorine, by a margin of 76% - 2%. Users experienced a very positive reaction to copper/silver ionization in that the incidence of eye irritation was cut by 16%; objectionable odors by l0o/a; bleaching of hair by 6%; and skin irritation by 4%.

XII Conclusions and Recommendations

Review of the data generated during the course of the study clearly supports the premise that copper/silver ionization technology is an effective and superior alternative to conventional swimming pool water disinfection by use of high levels of chlorine alone. The technology provides a high level of bacteria control, while lower chlorine levels result in substantial reduction of the production of trihalomethanes and increase substantially the enjoyment and satisfaction of the swimming experience for the pool user.

It is strongly recommended that the Massachusetts Department of Public Health after review of this evidence appropriately revise Chapter V of the State Sanitary Code to allow municipal Boards of Health to permit the use of copper/silver ionization technology with reduced levels of chlorine for indoor swimming pool disinfection.

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This study required significant cooperation from a wide and diverse group of individuals. Without their complete cooperation, this study could not have been accomplished. The authors and sponsors wish to express their gratitude for their cooperation and spirit of unselfishness. They are:

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BIBLIOGRAPHY
1. V.J.Cabelli. Water Sci. Tech. 21 13-21 (1989).
2. J.G. Jacangelo, V.P. Oliveri, and K Kawat.a. Mechanism of Inactivation of Microorganisms by Combined Chlorine. American Water Works Research Foundation. Denver, CO.
3. J. CarTell Morris in "Water Chlorination Environmental Impact and Health Effects" Volume 1. Robert L. Jolley (ed.) Ann Arbor Science Publishers Inc., Ann Arbor, Ifch. (1979).
4. Robert J. Jolley and James H. Carpenter in "Water Chlorination Environmental Impact and Health Effects" Volume 4. Robert L. Jolley (ed.) Ann Arbor Science Publishers Inc., Ann Arbor, Mich. (1983).
5. Showcase USA, 3rd Quarter, 52-4 (1990).
6. C.W. Chambers, C.M. Proctor, and P.W. Kabler. J. Am. Water Works Assoc. 54, 208- 216 (1962).
7. D.O. Cliver, W.K. Foell, and J.M. Goepfert. Final Technical Report. Contract NAS 9-9300. Food Research Institute, University of Wisconsin, Madison.
8. K. ZVuhrmann and F. Zobrist. Schwiez. Z. Hydrol. 20 218-254 (1958).
9. RA MacLeod, S.C. Kuo, and R Geliuas. J. Bacteriol. 93 961-9 (1967).
10. S. M Kutz et al, Proceedings Fourth Conference on Progress in Chemical Disinfection. GiIbeTt Janauer (Chairman) Dept. of Chemis-try, SUNY Binhampton.
11. M.T. Yahya et al, J. Environ. Health SI 282-285 (1989).
12. M.T. Yahya et al, Can J. Microbiol. 36 109-116 (1990).
13. L.K Landeen, M.T. Yahy and C.P. Gorba. Appl. Environ. Microbiol. 55 3045-3050 (1989).
14. M.T. Yahya et al, Int. J. Environ. Health Res. 1 76-86 (1991).

Microbiological Evaluation of Copper: Silver Disinfection Units
AUTHORS: Kutz SM, Landeen LK, Yahya MT, and Gerba CP

PUBLICATION REF: Proceedings of the Fourth Conference on Progress in Clinical Disinfection. State University of New York, Bighamton, New York, April 11-13, 1988

PURPOSE OF STUDY:
Although chlorination is the traditional method of disinfecting swimming pools, hot tubs, and cooling towers to prevent outbreaks of illness due to pathogenic bacteria, viruses, and protozoa, high levels of chlorine can cause eye and skin irritation was well giving rise to a noticeable chlorine odor. The authors evaluated electrolytically generated copper: silver ions alone and in combination with low levels of free chlorine as an alternative method of reducing the bacterial population in water.

MATERIALS AND METHODS:
The test medium was local well water which was subjected to chemical analysis, filtering, and pH stabilization and used at room temperature. Suspensions of the following organisms were prepared: Escherichia coli, Legionella pneumophila, Staphylococcus aureus, Pseudomonas aeruginosa, Salmonella TYPHII, Klebsiella terrigena, and Streptococcus faecalls. Approximately 1 ml of the selected bacterial suspension was added to 99 ml of test medium

containing (1) copper: silver ions in a concentration of 400 ug/liter copper to 40 ug/liter silver, (2) free chlorine (0.2 mg/liter) alone, or (3) a combination of copper: silver ions and free chlorine (quantities as above). Cultures were incubated and the bacterial colonies enumerated, after which statistical analysis were performed.

RESULTS:
The bacteria tested were inactivated more rapidly in a solution in which electrolytically generated copper and silver ions were added to low levels of chlorine than where either method was used separately. Some organisms were more resistant to treatment than others. In the experiments with Salmonella typehi and Klebsiella terrigena no viable cells were recovered after 30 seconds of exposure to either chlorine alone or to the combined regimen, indicating equal effectiveness when resistance to disinfection is low. On the other hand, Legionella pneumophilia titers decreased more than 5 log 10 values after 7 minutes of exposure to free chlorine (0.2 mg/liters) alone for the same length of time. Similarly, E. coli numbers were reduced by 4.2 log 10 by the combination regimen but by less than 3 log 10 after extended exposure to the copper: silver method without chlorine.

CONCLUSIONS:
The use of electrolytically generated copper and silver ions in combination with low levels of free chlorine proved an effective method of killing a wide range of pathogenic bacteria under controlled test conditions. Such bacteria are of potential concern in swimming pools and cooling towers.

Experiences of Hospitals Using Copper–Silver Ionisation for Legionella Control: Implications for the Evaluation of Other Disinfection Modalities”

Vol. 24 No. 8 August 2003
Janet E. Stout, PhD; Victor L. Yu, MD

BACKGROUND AND OBJECTIVES
Hospital-acquired Legionnaires’ disease can be prevented by disinfection of hospital water systems. This study assessed the long-term efficacy of copper–silver ionisation as a disinfection method in controlling Legionella in hospital water systems and reducing the incidence of hospital-acquired Legionnaires’ disease. A standardized, evidence based approach to assist hospitals with decision-making concerning the possible purchase of a disinfection system is presented.

DESIGN
The first 16 hospitals to install copper–silver ionisation systems for Legionella disinfection were surveyed. Surveys conducted in 1995 and 2000 documented the experiences of the hospitals with maintenance of the system, contamination of water with Legionella, and occurrence of hospital acquired legionnaires’ disease. All were acute care hospitals with a mean of 435 beds.

RESULTS
All 16 hospitals reported cases of hospital-acquired Legionnaires’ disease prior to installing the copper–silver ionisation system. Seventy-five percent had previously attempted other disinfection methods including superheat and flush, ultraviolet light, and hyperchlorination. By 2000, the ionisation systems had been operational from 5 to 11 years. Prior to installation, 47% of the hospitals reported that more than 30% of distal water sites yielded Legionella. In

1995, after installation, 50% of the hospitals reported 0% positivity, and 43% still reported 0% in 2000. Moreover, no cases of hospital-acquired Legionnaires' disease have occurred in any hospital since 1995.

CONCLUSIONS

This study represents the final step in a proposed 4-step evaluation process of disinfection systems that includes (1) demonstrated efficacy of Legionella eradication in vitro using laboratory assays, (2) anecdotal experiences in preventing legionnaires' disease in individual hospitals, (3) controlled studies in individual hospitals, and (4) validation in confirmatory reports from multiple hospitals during a prolonged time (5 to 11 years in this study). Copper–silver ionisation is now the only disinfection modality to have fulfilled all four evaluation criteria (Infect Control Hosp Epidemiol 2003;24:563-568).

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Neither Dr. Stout nor Dr. Yu have any financial interest in the companies manufacturing copper–silver ionisation systems. Specially, they are not officers, board members, stockholders, nor paid consultants for these companies. This survey was not supported by any of these companies and they had no input into the design or the conduct of this survey.

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Studies on Ionizations and Legionella

Chapter four : Some studies on ionization and Legionella

Efficacy of Copper / Silver Ions & Reduced Levels of Free Chlorine in Inactivation of Legionella pneumophilia.

AUTHORS: Landeen LK, Yahya MT, and Gerba CP

PUBLICATION REF: Applied & Environmental Microbiology 55: 3045-3050,1989

PURPOSE OF STUDY:

Relatively high levels of chlorination are known to be effective in inactivating Legionella pneumophilia in drinking water. However, high levels of free chlorine may degrade rapidly, especially at high temperatures, producing only temporary suppression rather than continuous disinfection. Also, high chlorine levels may lead to the development of resistant strains and be corrosive to plumbing fixtures. Therefore, the authors investigated the effectiveness of electrolytically generated copper and silver ions together with low concentrations as an alternative disinfection treatment.

MATERIALS AND METHODS:

Pellets of Legionella pneumophilia were suspended in samples of filtered well water and bacterial inactivation rates were determined using chlorination alone at low concentrations of 0.1, 0.2, 0.32, & 0.4 mg/liter. Then electrolytically generated copper & silver ions at copper to silver ratio of 200 and 20, 400 and 40, and 800 and 80 ug/liter were tested both separately and in combination with chlorination to evaluate any incremental bactericidal effect. The majority of experiments were conducted at room temperature with some tests performed at elevated temperatures (39 to 40). Inactivation rates for each experimental regimen were calculated by linear regression analysis. Buffering was avoided because phosphate buffer had been found to interfere with the disinfection efficacy of copper in previous test using Escherichia Coli.

RESULTS:

Bacterial inactivation with chlorination alone was progressively greater as concentrations were increased from 0.1 to 0.4 mg/liter. Although the rates were relatively slower, a similar inactivating effect was demonstrated in tests of copper and silver ions alone: the ratio of 800 (copper) to 80 (silver) ug/liter was significantly faster than ratios of either 200 and 20 or 499 and 40 ug/liter.
When the chlorination and copper/silver disinfection methods were combined, inactivation rates and amounts of bacterial reduction were enhanced. The 400 to 40 copper and silver regimen augments the measure rate of bacterial inactivation at all tested chlorine levels; the difference was statistically significant at a chlorine concentration of 0.4 mg/liter. Although reported by other investigators, significantly increased inactivation rates at high temperatures were not observed in this study.

CONCLUSIONS:

Electronically generated copper & silver ions increased the level of inactivation of Legionella pneumophilia achieved in filtered well water above the levels observed with free chlorine alone. This effect was consistent at all copper & silver ratios tested and at various low concentrations of chlorine. The improvement was statistically significant when 400 ug/liter of silver were added to a chlorine concentration of 0.4 mg/liter. Thus copper/silver ion treatment was shown to provide effective disinfection against Legionella pneumophilia while maintaining free chlorine levels sufficiently low to avoid the known disadvantages of relatively high concentrations.

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Experiences of Hospitals Using Copper–Silver Ionisation for Legionella Control
: Implications for the Evaluation of Other Disinfection Modalities"

Vol. 24 No. 8 August 2003

Janet E. Stout, PhD; Victor L. Yu, MD

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Moreover, no cases of hospital-acquired Legionnaires' disease have occurred in any hospital since 1995.

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Controlling Legionella in hospital water systems: experience with the superheat-and-flush method and copper-silver ionization.

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Special Pathogens Laboratory, Veterans' Affairs Pittsburgh Health Care System, University of Pittsburgh School of Medicine, PA 15240, USA.

OBJECTIVE: To evaluate the effect of copper-silver ionization on Legionella colonization and nosocomial legionnaires' disease and to compare the efficacy of metal ions versus the superheat-and-flush method of disinfection. DESIGN: Prospective determination over a 36-month period of copper and silver ion concentrations in the recirculating hot-water system, Legionella colonization of the hospital water distribution system, and cases of nosocomial legionnaires' disease. Retrospective comparison of results with the previous 13 years, during which the superheat-and-flush method was used. SETTING: The Pittsburgh Veterans' Affairs Health Care System (University Drive Division) acute-care hospital. INTERVENTION: Three copper-silver ionization systems were installed on the hot-water distribution system in November 1994. RESULTS: The average number of cases of legionnaires' disease per year and the percentage of distal sites positive for Legionella pneumophila for the superheat-and-flush method versus the copper-silver ionization method was six cases with 15% positivity versus two cases with 4% positivity, respectively. The reduction in Legionella colonization after copper-silver ionization was significant ($P<.05$) compared to the superheat and flush. Mean copper and silver ion concentrations (mg/L) were 0.29 and 0.054 from hot-water tanks, and 0.17 and 0.04 from distal outlets, respectively. CONCLUSIONS: We conclude that a properly maintained and monitored copper-silver ionization system was more effective than the superheat-and-flush method for reducing the recovery of Legionella from the hospital water distribution system.

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Efficacy of thermal treatment and copper-silver ionization for controlling Legionella pneumophila in high-volume hot water plumbing systems in hospitals.

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BACKGROUND: Thermal treatment and copper-silver ionization are often used for controlling Legionella pneumophila in high-volume hospital plumbing systems, although the comparative efficacies of these measures in high-volume systems are unknown. METHODS: Thermal treatment of a hot water circuit was accomplished by flushing hot water (> 60 degrees C) through distal fixtures for 10 minutes. Copper-silver ionization was conducted in three circuits by installing units into return lines immediately upstream from hot water tanks. Recovery rates of L. pneumophila were monitored by culturing swab samples from faucets. Concentrations of copper and silver in water samples were determined by atomic absorption spectrophotometry. RESULTS: Four heat-flush treatments failed to provide long-term control of L. pneumophila. In contrast, ionization treatment reduced the rate of recovery of L. pneumophila from 108 faucets from 72% to 2% within 1 month and maintained effective control for at least 22 months. Only three samples (1.9%) of hot water from faucets exceeded Environmental Protection Agency standards for silver, and none exceeded the standards for copper. Of 24 samples obtained from hot water tanks, 42% and 50% exceeded the silver and copper standards, respectively. CONCLUSIONS: Copper-silver ionization effectively controls L. pneumophila in high-volume plumbing systems and is superior to thermal treatment; however, high concentrations of copper and silver can accumulate at the bottom of hot water tanks.

Copper in the health arena

Chapter five : Information on copper in the health arena.

Copper and Its role In public health

Christopher M. Lee, Ph.D.

Introduction

This paper examines the issues that surround the role of copper in public health. It concludes with a look at the opportunities that may exist for the copper industry to develop and introduce copper and copper alloy products that could make additional contributions to the protection of public health, including some steps that might be taken to develop such products.

Metal ions have been used for centuries by many cultures to effectively disinfect fluids, solids and tissues. There are three modern copper products for which this is a valuable attribute. First, copper plumbing tube, where dissolution results in the presence of copper ions in potable water. Evidence exists that the presence of these ions will act to a reduce the risk of pathogens in drinking water. Second, copper sheet that may be used for food preparation surfaces or for roofing, and, third, copper powders that may be incorporated in paints used in hospitals to prevent cross-contamination or on ship hulls to prevent bio-fouling. There is evidence for the benefits of using copper in each of these product fields, including for the protection of public health.

The attributes of copper that suggest it has potential value and these need to be assessed in light of the current circumstances and issues surrounding disinfection of surfaces to prevent infection and cross-contamination from micro-organisms.

Copper a Natural, Essential Micro-Nutrient With Toxic Properties

Copper is a metal of great contradictions. It is natural, it is essential as a micro-nutrient for most living organisms and without it human health and well-being are compromised. Copper is a critical component of many enzymes that control body functions yet, under some circumstances, this transition metal is highly toxic and the gap between essentiality and toxicity may be very small. In healthy organisms the balance between sufficiency and excess is under exquisite control at the molecular level. When this homoeostatic mechanism is disturbed, as it can be by small mutations in the genetic code for production of the key Wilson's and Menke's proteins, the results can be devastating. Furthermore, in some cases relatively low levels of copper of the order of several mg/l can cause acute nausea in humans. Small though the risk is of these problems they have received a lot of attention from the regulatory community concerned with public health, especially in regard to drinking water. So, when considering the development of copper products to protect human health it is important to be conscious of the fact that it is done it in a regulatory environment that is already highly sensitized and concerned about the potential effects of copper products on human health.

Copper ions are highly toxic and, indeed are regarded as among the most toxic to heterotrophic bacteria and to viruses. This is of course exactly what is required but it is perhaps ironic that the benefits sought in public health applications of copper products rely on its toxicity. As with copper in drinking water the regulatory community is sensitized to this toxicity issue and in many jurisdictions regulators are presently listing copper as an element needing special attention, regulatory controls and reductions in use. As in the case of pesticides it will be necessary to demonstrate that copper products can achieve their goal of inactivating pathogens without impacting populations of non-target organisms, including in this case, the human population.

To develop commercial products based on copper's anti-microbial properties these contradictions must be confronted. Regulators and the consumer must be convinced that copper products, such as plumbing tube, sheet and powders, may be a good contribution to the solution of a growing problem. That problem is, the development of increasing resistance of micro-organisms to the synthetic organic antimicrobial chemicals and antibiotics.

The decline in the efficacy of antibiotics because of their over prescription and particularly as a result of their use in low concentrations as growth promoters in farmed animals such as chickens, pigs and cattle is troubling. A similar story is found with our use of antimicrobial agents, that is, disinfectants, in the commercial and domestic setting. Hundreds of these antimicrobial products have been made and sold by the consumer goods companies over the last 50 years and society, especially in the developed countries, is pouring thousands of gallons of these agents onto surfaces and into waste streams. As a result, the microbial population is evolving resistance to these chemical agents at a rapid rate and research to invent new molecules is struggling to keep pace. These circumstances are increasing the risk of threats to public health.

The copper industry is not in the antibiotic business but anywhere that disinfectants are used there is a potential opportunity to introduce copper and copper alloy products. The principle issues are cross-contamination and cross-infection. Copper is unlikely to be the whole answer but it may make an important contribution in circumstances where multiple defence strategies are needed. ?

These circumstances likely to be found in commercial food processing plants, commercial kitchens, hospitals and the domestic kitchen. These sites are engaged in a war against cross-contamination and cross-infection and winning that war depends, at least in part, on having available effective disinfectants. The problem is also seen on farms where the microbial populations in the faeces of animals not only survive in soil for many months, but can wash through into shallow aquifers potentially, and in some cases, actually contaminating the drinking water supplies. For example, this is believed to have been the cause of an outbreak of gastro-intestinal illness caused by E. coli O157-H7 in well water at the New York State Fair. Field washing of vegetables for market has also been shown to be a source of infection for this reason as a result of using untreated well water from shallow aquifers.

However, even though these cases present substantial concerns, it must be said that in properly treated public drinking water supplies, the risk of infection from pathogens is generally low.

Surfaces are a different story. In public and private toilet facilities, kitchens and hospitals we are vulnerable to cross-infection from both aerosol and surface transfer of pathogenic organisms. Gerba and his team at Arizona State University has demonstrated the extent of this problem in practice in the domestic setting. The survival of bacteria in the kitchen and bathroom in the face of application of disinfectant products is increasing. Interestingly, he has found that it is the most diligent housekeeper who frequently washes and wipes surfaces that often has the worst and most widespread microbial surface contamination. This can result from the repeated use of sponges and other wipes that present the microbial population with a constant low level of disinfectant to which they have adapted resistance. He has also shown that many bacteria can survive through laundry wash cycles, with their modern low temperature bleaching systems, which now require water of only 60C or less, when clothes used to boiled. He has also found that the bacteria can even survive the drying cycles, which may be as short as 20 minutes.

Another source threatening to present cross-contamination problems is the development of processes to allow re-use of domestic grey water, especially in the desert southwest of the United States where water availability is becoming limited. Re-use may include garden irrigation and toilet flushing. Again, Gerba and his colleagues at Arizona State are studying the implications of this practice for public health.

Development of Resistance to Metals

Given the extent of the problem of developing resistance to antibiotics and disinfectants with synthetic organic microbial agents, an important question for the development of copper products is whether the continuous exposure to copper will evoke a similar response and evolution of resistance. There is evidence that at least some pathogens and other micro-organisms have developed resistance to copper and it will be necessary for industry to assess whether this would become a matter of public health significance.

Silver (1996) in a review of what is known of metal resistance in pathogens comments that in his laboratory the view is that toxic metal resistance “arose shortly after prokaryotic life started” because of the presence of metals throughout the environment. In a more recent and brilliant review of this topic Neis (1999) of the Institit für Mikrobiologie at the Martin-Luther-Universität notes that resistance to heavy metals is “just a specific case of the need of every cell for a homeostasis system.” Organisms studied and providing clues to resistance mechanisms include the enteric bacterium Escherichia coli isolated from pig faeces, Enterococcus hirae, Streptomyces lividans, Pseudomonas and Synechococcus. Interestingly, Cooksey (1996) reviewing resistance mechanisms in the plant pathogens concludes that the fundamental mechanism is of ancient origin and not a recent phenomenon induced by “mobilization of copper from human activities.” It is self-evident that if copper is essential the resistance mechanism cannot be allowed to deplete the cell of copper.

The literature suggests that bacterial cells use two-component systems to regulate copper homeostasis and provide resistance to excess (Figure 2). These two systems are the P-type ATPases and a plasmid system of four structural genes encoding for four proteins manifested in the inner and outer cell membrane and the periplasm. In the gram positive bacteria, the P-type ATPases detoxify copper by efflux. In the gram negative bacteria such as Pseudomonas the four protein system detoxifies copper by binding it in the periplasm or near to the outer cell membrane. In this latter case the bacteria can turn blue due to the sequestration of copper in the membrane. The P-type ATPases are familiar from their central role in the homoeostatic mechanisms worked out for uptake and efflux of copper in humans.

It is clear that the potential for resistance is present in pathogenic bacteria and is something that must be investigated as the applications of the antibacterial properties of copper are explored.

A Wide Range of Pathogens Respond to Copper

A wide range of micro-organisms (Figure 3) have been shown to be susceptible to copper surface effects. These include the organisms shown on this slide. All of these organisms offer a threat to human health either from contaminated water or food. In some cases, such as rotavirus, as many as 5 million child deaths per year are recorded in developing countries.

Although there is evidence that micro-organisms have the systems to resist the toxic effects of copper we also have ample empirical demonstrations of its useful impact on pathogens. These properties have been widely and effectively used over many hundreds of years up to modern times.

Copper plates were attached to the hulls of ships to prevent growth of seaweeds and barnacles. Today, advanced copper based paint systems using copper oxide powder are widely used on ship hulls for the same reason. Even shore- based facilities with wooden pilings in the seawater have been sheathed with copper and copper-nickel alloys. Nets of copper-nickel have been used by fish farming enterprises and power stations have used admiralty brass and other copper-based alloys for their condensers, all chosen for resistance to corrosion and to prevent fouling growths that will reduce performance in these high throughput systems. It is worth pointing out that in 1999 a retrospective analysis by Paquin (1999) of the copper released from the condensers of power generating facilities around the USA demonstrated that there was never an impact problem with the copper in the discharges. This re-analysis was based on the recent research information and new models that take into account of the bioavailability of copper in natural waters and has demonstrated that the toxic species of copper were not available to exert effects.

Copper roofs are well-known to have a long life and do not allow any microbial growth. This attribute of copper is used by at least one manufacturer of synthetic roofing shingles who incorporates copper oxide into granules so that it is slowly released over time to prevent the growth of a blue-green algae on the roof slopes facing away from the sun.

Recovery of Viruses After Exposure to a Range of Plumbing Materials

Using plumbing test rigs of copper and galvanized steel, Slade and Fricker (1996) at Thames Water Authority demonstrated that water containing polio virus, coxsackievirus types B2 and B4, Echovirus 4 and simian rotavirus SA11 were reduced after 16 hours contact by 98% and 82-92% respectively (Figure 4).

Biofouling by Bacterial Consortium and Colonization by L. pneumophila

Walker et al (1993) examined the impact of plumbing materials on the growth of a mixed bacterial consortium including, Pseudomonas, Flavobacterium, Alcaligenes, Methylobacterium spp., and the pathogenic bacterium Legionalle pneumophila. Using copper, polybutylene, polyethylene and cPVC they demonstrated that in soft, moderately hard, and hard potable waters at different temperatures the surface biofouling was substantially less on the copper compared to the plastic materials and the planktonic phases were substantially less when copper was present (Figure 5).

Survival of E. coli O157-H7 on Metal Surfaces

In a more recent study that you will hear about later from Dr. Keevil, Maule et al (1999) showed that E. coli O157-H7 died in just 4 hours on copper surfaces at room temperature (20oC) and in 14 hours at chill temperatures (4oC). The effect was also seen with brass but was somewhat slower (Figure 6). Stainless steel compared unfavourably. In model water systems this organisms colonized biofilms formed on copper less than stainless steel or polybutylene.

Importance in Potable Water
Copper and chlorine can act synergistically to inactivate bacteria and viruses and reduce the contact time to achieve the same pathogen reductions as either alone. It has also been shown that in the presence of copper less monochloroamine is required for the same effect which has eh benefit of reducing the risk of THM (TriHaloMethane) compound formation (Straub et al 1995).

Synergistic Inactivation of E. coli and MS2 Coliphage by Monochloramine and Cupric Chloride
The data (Figure 7) showed that in 2 hours exposure to 0.4 mg/l copper chloride reduced the bacteriophage MS2 by only 0.5 log10 unit and did not reduce E.coli at all. When exposed to 5 mg/l of monochloramine for 2 hours MS2 was reduced by 3 Log10 while E.coli was reduced by 6 Log10 in just 1 hour. When exposed to a combination of 5 mg/l of monochloramine and 0.1 mg/l copper chloride a 3 Log10 reduction was achieved in just 10 minutes. In the case of E. coli inactivation was achieved on exposure to 2.5 mg/l monochloramine and 0.4 mg/l copper chloride and the period halved when the concentration if copper was doubled to 0.8 mg/l.

Synergistic Effects of Copper, Silver and Free Chlorine on Naegleria fowleri
Similar synergistic effects have been demonstrated for copper, silver and free chlorine using the amoeba Naegleria fowleri (Cassels et al, 1995). With no disinfectant the amoebae were reduced by 99% in 123 hours. In the presence of chlorine alone at 1.0 mg/l they were reduced by 99% in 6.1 minutes and in only 4.4 minutes in the presence of 1.0 mg/l chlorine and a 0.4/0.04 mg/l mixture of copper and silver (Figure 8).

These are dramatic effects and differences in efficacy and, more interestingly, the concentrations are at realistic levels. Copper in drinking water averages around 0.1 mg/l (range 0.001 to 4 mg/l) in the United States and, since chlorine is the most common disinfection process in the USA, it is reasonable to conclude that the presence of the copper enhances the effect of the chlorine and extends the safety margin further reducing the risk of infection.

Clearly, despite the mechanisms that bacteria have to detoxify copper, these mechanisms can be overwhelmed. This is a probably an area where additional research would be useful.

Straub et al (1995) give a useful overview of the mechanism of effect of metal ions on bacteria and viruses. Copper may bind with sulphydryl groups and impair respiration and may also bind to nucleic acids. In the case of viruses copper is thought to bind with a biological target where it is reduced then re-oxidized by peroxide which generates damaging hydroxyl radicals. In the presence of monochloramine and chlorine there may an impact on the capsid of the virus and destruction of RNA. Free chlorine acts more rapidly than the monchloramine.

The Path Forward
The work of Keevil and others has amply demonstrated that copper surfaces whether in the form of plumbing tube or work surfaces, can deactivate a range of bacteria and viruses. Copper alone is, of course, too soft for use as a work surface and must be hardened by alloying with another metals. It is likely that alloying will reduce the effect has been observed in the recent experiments. There are a number of options available.

Potentially Useful Copper Alloys
An enormous range of alloys exists and they can be produced with almost any mechanical property desired, including formability, and desirable properties such as corrosion resistance and color.

The potentially useful alloys for applications taking advantage of the anti-microbial properties of copper are shown in Figure 9. These include a range of brasses containing from 10% to 40% zinc, phosphor bronzes containing 5% to 10% tin, aluminum bronzes containing 8% aluminum or 8% aluminum with 2% nickel, copper nickels containing 5% to 30% nickel, and finally, the nickel silvers containing 17% to 27% zinc and 10% to 18% nickel. We think that, in addition to copper, we might want to use Muntz Metal containing 40% zinc as a control. The aluminum bronzes have good corrosion resistance and are used in chemical equipment for this reason. However this resistance is not as good as the nickel alloys which have the best corrosion resistance. At the highest (30%) nickel content the alloy looks like stainless steel. The nickel silvers can also look like stainless steel but are softer and their corrosion resistence is better than brass.

All metals and alloys will corrode, including stainless steel. Stainless steel is 18% chromium and 8% nickel. It’s famous resistence to corrosion is conferred by the chromium which allows the rapid formation of protective oxides. The inclusion of nickel allows for easier forming but it also assists in protective oxide formation.

The purpose of using copper alloys is to harden the surface to make it more durable and more commercially viable. However alloying of copper will also increase its corrosion resistence and this may affect its efficacy against pathogens either by reduction of potency or by slowing down the effect. In the view of the expert metallurgists of CDA Inc. in the USA, the copper nickel range offers the best prospect of a commercially viable product that still retains an antimicrobial action. Although corrosion resistance increases with nickel content so does the cost and there will also need to be a balance struck between performance and cost. The aluminum bronzes and nickel silvers are both corrosion resistant, better than brass but not as good as the copper-nickel.

Some of the reasoning for this comes from prior research on copper nickel alloys by INCRA, the predecessor organization to ICA which focused on technological research for copper products. Copper nickel alloys are used in applications as varied as sheathing for wooden pilings, fishing cage netting, and power plant condenser tubing taking advantage not only of their strength but their antifouling properties.

Research and Development - Next Steps: Food Processing Applications
The next steps will be to run concurrent experiments to determine the rate and extent of pathogen inactivation using a range of candidate alloys with pure copper and Muntz metal as controls. It will also be important to extend the range of pathogens incorporated into the

experimental regime. Also under consideration will be the examination of the coupled effect of copper alloy surfaces and powerful oxidants such as chlorine bleach for which earlier research appears to show a synergistic effect.

Proof of the ability of commercially durable alloys to inactivate pathogens will lead to feasibility testing of products for various applications. In addition to food handling, processing and storage surfaces the demonstration of hard alloys retaining their antimicrobial properties opens up the prospect of developing key components of food process machinery.

An important aspect of any applications research must be the determination that there are no toxicological or taste implications associated with the contact of food with the alloys. It is well known that copper cooking vessels are usually tinned, in part to avoid this problem. Acidity is the condition of particular concern even though Keevil and others showed that such stress tends to enhance anti-microbial effects. The speculation is that unless there was actual cooking involved or prolonged contact with acid fluids such problems are unlikely but this must be demonstrated.

A full-blown health risk assessment would need to be done to demonstrate that no human health risk exists. Similarly, it can be anticipated that there would be a need to demonstrate that there are no adverse effects on non-target organisms especially in sewage treatment facilities receiving the waste discharge.

Conclusion

The evidence suggests that copper products already contribute to maintenance of public health. There is also evidence that they have the potential for development of other applications, especially in the food processing industry. Copper is not likely to be the whole answer to what is perceived to be a public health problem but it may add to our range of options to fight a growing problem. Public health threats from pathogenic organisms entering the food chain are increasing in both the developed and developing world for number of reasons. If a commercially viable alloy can be found, copper may provide a natural option to control the incidence of cross-contamination and reduce the chance of infection in a number of circumstances related to food processing and handling in both the commercial and domestic setting. It is unlikely that copper or its alloys would present unacceptable risks to the consumer from these potential applications but that would have to be demonstrated.

References

Silver, S., 1996. Bacterial Resistance to Toxic Metal ions - A Review. Gene 179, pp 9-19.

Neis, D.H., 1999. Microbial Heavy-Metal Resistance. Appl Microbiotechnol. 51: pp 730-750.

Cooksey, D.A., 1996. Molecular Genetics and Evolution of Copper Resistance in Bacterial Plant Pathogens, pp 79-88. In: T.M. Brown (ed) ACS Symposium Series; No. 645. Molecular Genetics and Evolution of Pesticide Resistance. Amer. Chem. Soc.; Washington, D.C. USA, 265 pp.

Paquin (1999)

Slade, J. and C. Fricker, 1996. An Investigation into the Effects of Copper and Other Domestic Plumbing Materials on the Survival or Waterborne Viruses. ICA Report No.143.

Walker, J.T., J. Rogers and C.W. Keevil, 1993. The Influence of Plumbing Tube Material, Water Chemistry and Temperature on Biofouling of plumbing Circuits with Particular Reference to Colonization of Legionalla pneumophila. ICA Project No. 437A

Maule, A., J.T. Walker and C.W. Keevil, 1999. The Survival of Escherichia coli O157-H7 in Biofilms on Copper, Stainless Steel and Plastic Plumbing Materials and as Dried Deposits on Copper Stainless Steel and Brass. ICA Project No. 483.

Straub, T.M., C.P. Gerba, X. Zhou, R. Price and M.T. Yahya, 1995. Synergistic Inactivation of Escherichia coli and MS2 Coliphage by Chloramine and Cupric Choride. Wat. Res.: 29:3, pp 811-818.

Cassels, J.M., M.T. Yahya, C.P. Gerba, and J.B. Rose, 1995. Efficacy of a Combinedd System of Copper and Silver and Free Chlorine for Inactivation of Naegleria fowleri Amoebas in Water. Wat. Sci. Tech., 31:5-6, pp 119-122.

: Infect Control Hosp Epidemiol. 1998 Dec;19(12):911-4.

The Use of Ionic Copper in the Treatment of Arthritis
by Seldon Nelson, D.O.

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The Roger Wyburn-Mason and Jack M. Blount Foundation for the Eradication of Rheumatoid Disease

"Medical data is for informational purposes only. You should always consult your family physician, or one of our referral physicians prior to treatment" -
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Editor's Note: Dramatic clinical improvements in some cases of rheumatoid disease have resulted with the use of new resin coated copper granules. This paper covers the rationale and techniques of treatment. Copper is considered a trace mineral, and in this form, it is used as a dietary supplement, as rheumatoid patients are so often deficient in this substance. Normal and healthy persons usually show no reaction to these doses of copper, and no severe effects or reactions have been reported. Much clinical testing and follow-up reports must be obtained before the method is recommended for general use.

According to the research by the late Dr. Roger Wyburn-Mason, the cause of rheumatoid arthritis and some other chronic and rheumatoid diseases may be an amoeba parasite, amoebae limax or Naegleria. These organisms, or whatever is eventually proved to be a cause for these conditions, are sensitive in varying degrees to various antibiotic substances.

Basic research has been done which indicates that the causative agents or rheumatoid diseases are susceptible of being destroyed by minute amounts of pure metallic copper. For example, even water contaminated with limax amoebae can be cleansed by running through copper pipe. Since it "is not possible to run a person thru a pipe of copper," the copper ion must be given to a person in another form. While Dr. Wyburn-Mason reported some success with copper sulfate, less toxic forms have been sought by clinical investigators.

It has been found that pure metallic copper can be prepared and administered in the form of granules in microgram quantities on an ion exchange resin.*****

This is successfully used as a nutritional supplement in patients deficient in this element, which appears to make them more susceptible to chronic illnesses of the rheumatoid type.

Copper is an essential trace mineral in human diets, consumed daily in some foods, and contributes to health in the formation of new blood cells, the red blood cells and the leukocytes which help the patient to fight infections.

Some physicians have found that when copper of this type is used in microgram quantities, it is a very conservative treatment, obtaining therapeutic benefits in ridding the body of toxic parasites such as amoebae without risking toxic reactions or serious side effects.**1**

Of course, as with any heavy metal, taking too much copper or for too long a time can produce adverse effects which can easily be detected and avoided or treated.**2**

Ceruloplasmin and serum copper levels are indicators for therapeutic and also toxic levels of copper permitting periodic evaluations by the physician. As with any method of arthritis treatment, if effective results are obtained, certain baseline laboratory values, including a SMAC-24, a CBC, and serum copper levels and ceruloplasmin levels must be determined for later reference.

Contraindications to this treatment may be any abnormal neurological signs or symptoms, although some success with this therapy has been seen in one neurological disease where it seems that copper deprivation may be a factor.**3**

The Treatment Program

The following protocol is utilized in treating patients with active rheumatoid disease:

When the patient has signed an informed consent to a new type of food supplement to correct a probable essential trace mineral deficiency, a test amount of the ionic copper granules can be given in the office. This may be as few as 5 [granules or micrograms?] or as many as 20, although 15 is the average amount for a 150 pound adult male.

As one becomes familiar with the treatment, a "feeling" of the proper amount for each patient will develop. In a short time, clinical judgment will determine the initial dose and the amount to be increased each day, usually divided into three equal doses, taken on the tongue and washed down with a half glass or more of water.

The first treatment program will take about six weeks and the patient should have a favorable response, which may be from moderate relief and improvement of signs and symptoms to a complete or permanent remission.

In addition to the copper granules, patients may take their customary medicine for arthritis discomfort, and a biologically active nutritional supplement is also used.**4**

As with all antibiotic therapy, the substance used is usually given to achieve a specific blood level. For the use of copper as a nutritional supplement and to build up the natural resistance of the body to the infective agent, no definite blood levels have been determined. They may be different for different patients. Clinical observations along with the specific blood levels for the particular patient will act as a guide should it seem desirable to repeat the program.

When the therapeutic level of copper in the blood is reached, then the susceptible microorganisms, whose presence is the probable cause of the disease, are killed by the chemical activity of copper ions. This is an all-encompassing phenomenon, and it affects the entire population of microorganisms in question. But the killing of the susceptible microorganisms may, and usually does, result in the production of a Herxheimer reaction. (The patient may feel that the arthritis is getting worse, or that a flare-up or aggravation of the disease is occurring. It should be explained to the patient that this is an "expected reaction" probably caused by release of toxic substances from the killed pathogenic organisms, or the amoebae in rheumatoid arthritis, and not by live microorganisms of any exacerbation of the disease.)**5**

The extent of the Herxheimer reaction is directly related to the number of the microorganisms being destroyed, the area of the body that has been affected by the rheumatoid disease, the rate of release of toxins from the dead microorganisms and the patient's own resistance or sensitivity to foreign proteins.

Rarely, some patients experience a severe reaction appear "really sick." But the whole secret of success with this treatment with copper granules is to get the patients past the Herxheimer reaction with a minimum of discomfort and apprehension about the apparent flare-up of the disease.

This is usually best accomplished by getting past the stage of the reaction as quickly as possible, as opposed to stringing out the process and prolonging the agony.

Start the patient on whatever level that it appears can be comfortably handled. For example: Prescribe an initial dose of 10 granules. This is to be taken three times a day the first day. Then increase the total dose by 5 granules each day, observing the reactions and tolerance. If this does not provoke a reaction, then increase the daily total by 10 granules per day until the patient is taking 75 to 80 granules per day. This level is maintained for 10 to 14 days. Then, the maximum dose is achieved by going to 90 granules a day. Then the Herxheimer reaction should be safely passed, permitting the patient to take 90 granules 2 times a day for two weeks, then the lesser dose of 100 granules once a day for two weeks. Then the copper medication is stopped and the clinical and laboratory evaluations repeated to judge the state or progress and recovery of the patient.

The treating physician should expect and look for signs of a Herxheimer reaction in his patient once the copper granule treatment has been started. It may be very mild and immediate, taking only a few seconds, or it may develop later, several hours to several days to manifest itself. Since it is due to the killing of the microorganisms responsible for the disease, it is a clinical confirmation of the diagnosis of rheumatoid disease as well as an indication that the patient will benefit for the treatment with improvement or complete recovery.

The reaction to the copper granules is not a drug reaction. When the granules are given to a control who is a healthy subject, no Herxheimer reaction occurs.

If the patient has had a treatment with gold therapy, penicillamine or cortico-steroids currently or recently, or for long periods of time, the usual physiological Herxheimer response may be altered. In some of these patients, it may be entirely absent. This probably indicates that the normal immunological responses of the patient's body has been altered by these drugs. It may also indicate an acquired resistance of the pathological organism responsible for the disease to antibiotic agents.

What should the patient be told to expect in the form of a Herxheimer reaction? These symptoms may occur in order of their frequency and severity —

1. A dry, "funny" or metallic taste in the mouth.
2. Increased aching and pain in the joints.
3. Muscle fatigue and a "burning" sensation.
4. Loss of appetite, nausea, occasional vomiting.
5. Diarrhea or constipation, cramping, gas.
6. Some tissue or joints swelling, redness, local heat and inflammation.
7. Increased muscle and joint stiffness.
8. Low fever and night sweats.

Other rare signs and symptoms may temporarily appear, mimicking other rheumatoid diseases: Skin manifestations, eruptions, scaling, eczema, and psoriatic appearing lesions. If the organisms have been lodged in the tissues of the central, peripheral or autonomic nervous systems, there may appear neurological or sensory symptoms, including the special functions of vision, hearing, taste, and smell.

Since Rheumatoid diseases are systemic in nature, the endocrine tissues seem to have an affinity for the organisms causing the infection. In the Herxheimer reaction, there may be significant changes, such as alteration of the menstrual cycle, decreased need for insulin in diabetes, less thyroid requirement in hypothyroidism, and reduction in the signs and symptoms of endometriosis. Headaches are not uncommon, and psychological changes may be noticed temporarily such as unexplained anger, depression, irritability, listlessness, fatigue, etc. The patient must be reassured regarding these phenomena, and they may be reduced or prevented by appropriate treatment. Complete suppression, however, removes a significant clinical observation which the physician uses as a treatment guide.

However, in some patients, it may be necessary to treat it or to suppress the Herxheimer reaction to help the patient get past this stage of treatment with less discomfort and less physical disability. This may be done in one of several ways. First, the daily dose of copper granules may be reduced by one half or more for two or three days, or until the uncomfortable symptoms subside, then beginning again on a lower level. Second, the medication may be completely halted for a week or so, then begun with a covering dose of symptomatic medications. Third, medications may be taken along with the copper granules without conflict or weakening of their therapeutic effect. These may include analgesics such as aspirin and the non-steroidal anti-inflammatory drugs, muscle relaxants and antiemetics. Fourth, an initial dose of depo-steroidal drug may be administered once a week until the Herxheimer symptoms have subsided or are past.**6**

Then, when the Herxheimer reaction has been suppressed, the disease should be treated more vigorously, increasing the dose of the copper granules to 30 granules three times a day and up to 90 granules twice a day for two weeks, then 100 granules once a day for two weeks. Then the medication — or food supplement — as it should be considered, is stopped. By this time, the patient's body has been saturated with a high and normal amount of copper sufficient to control the active form of the disease.

The philosophy behind the copper granule use in rheumatoid disease is to restore normal tissue levels of copper and then increase these to tolerance to inhibit and kill microorganisms responsible for these chronic systemic infections. While it will be important to continue research on the nature of these infectious forms, protozoa, mycoplasmas, or viruses, it is not necessary to identify the cause to get a good treatment result.

The copper granules permit the patient to be treated at a variable rate according to his own tolerance to the signs and symptoms of the Herxheimer reaction. The rate of "kill-off" of the microorganisms is directly related to the amount of copper granules used. Each copper granule will kill a certain amount of susceptible microorganisms. Ten granules will kill ten times as many. Fifty granules will kill fifty times as much. So the rate at which the patient can be treated, and his or her disease controlled, is dose related.

No serious reactions have developed with this treatment. There are no contraindications known to date. And there are no drug sensitivities or sensitivity problems with copper granules, since it is a normal physiological trace mineral in the human body.

Conclusions

Metallic copper in pure ionic granules has been successful in treating the rheumatoid diseases when used as a dietary supplement and increasing the amounts up to tolerance of the patients to Herxheimer reaction symptoms. No adverse or metal toxicity reactions have occurred to this form of copper in the amounts recommended. Recovery and improvement in rheumatoid signs and symptoms with this new method suggest its importance as a new road to health for the patient.

* Copper micro-granules were supplied as MEIRA™ Cu by Midwest Metabolic, Inc., 1435 East Grand River Avenue, Williamston, MI 48895; distributed by D.S.D. International Ltd., 640 E. Purdue, Suite 106, Phoenix, AZ 85020; (800) 232-3183; (602) 944-0104; Viotron International, 8122 East Fulton, Ada, MI 49301; (800) 437-1298.

Conclusion

From a public health perspective we feel that it is important to consider all the information above regarding swimming pool sanitation and make decisions based on all the facts considered.
If we can help that process by this paper, our goal was successful.