Miller, D. L. (1986). "EFFECTS OF A HIGH-AMPLITUDE 1-MHZ STANDING ULTRASONIC-FIELD ON THE ALGAE HYDRODICTYON." Ieee Transactions on Ultrasonics Ferroelectrics and Frequency Control **33**(2): 165-170.

Al-Hamdani, S., C. Burnett, et al. (1998). "Effect of low-dose ultrasonic treatment on Spirulina maxima." Aquacultural Engineering **19**(1): 17-28.

Spirulina maxima exposure to ultrasound (16 and 18 W) for 5 s generally resulted in decrease in growth, protein concentration, and superoxide dismutase (SOD) activity, while chlorophyll a concentration was not significantly affected at the 5% level. However, lower doses (8 W) of ultrasound showed a 5% increase in growth in samples receiving a one-time dose of ultrasound on the first day and day 7 of the experiment (US-D-1,7) compared to the control and the ultrasound every other day treatment (US-EOD). Chlorophyll a concentration was not significantly different between the control and US-D-1,7 treatment, but increased in the US-EOD treatment. In addition, protein concentration and SOD activity were decreased in both of the ultrasound treatments compared to the control. For the production of Spirulina on an industrial scale, low doses of ultrasound may provide an environmentally safe method for enhancing the growth of this organism. Conversely, higher doses of ultrasound may provide an environmentally safe method for reducing the growth of harmful cyanobacterial species in growth systems for animal aquaculture (C) 1998 Elsevier Science B.V. All rights reserved.

Mark, G., A. Tauber, et al. (1998). "OH-radical formation by ultrasound in aqueous solution - Part II: Terephthalate and Fricke dosimetry and the influence of various conditions on the sonolytic yield." Ultrasonics Sonochemistry **5**(2): 41-52.

Terephthalate and Fricke dosimetry have been carried out to determine the sonolytic energy yields of the OH free radical and of its recombination product H2O2 in aqueous solutions under various operating conditions (nature of operating gas, power, frequency, temperature). For example, in the sonolysis of Ar-saturated terephthalate solutions at room temperature, a frequency of 321 kHz, and a power of 170 W kg(-1), the total yield [G((.) OH)+2 G(H2O2)], equals 16 x 10(-10) mol J(-1). This represents the total of (.) OH that reach the liquid phase from gas phase of the cavitating bubble. The higher the solute concentration, the lower the H2O2 production as more of the OH free radicals are scavenged, in competition with their recombination. Fricke dosimetry, in the absence and presence of Cu2+ ions, shows that the yield of H atom reaching the liquid phase is much lower, with G(H-.) of the order of 3 x 10(-10) mol J(-1). These sonolytic yields are smaller in solutions that are at the point of gas saturation, and increase to an optimum as the initial sonication-induced degassing and effervescence subsides. The probing of the sonic field has shown that the rate of sonolytic free-radical formation may vary across the sonicated volume depending on frequency and power input. (C) 1998 Elsevier Science B.V. All rights reserved.

Lee, T. J., K. Nakano, et al. (2001). "Ultrasonic irradiation for blue-green algae bloom control." Environmental Technology **22**(4): 383-390.

A novel application of ultrasonic irradiation for rapid control of blue-green algae (BGA) bloom was investigated. Potassium iodide (KI) experiments demonstrated that frequency and input power are the major factors that affect the ultrasonic irradiation intensity. Short exposure (3 s) to ultrasonic irradiation (120 W input power, 28 kHz) effectively settled naturally growing BGA suspension. Electron microscopy reconfirmed that sedimentation was caused by the disruption and collapse of gas vacuoles after ultrasonic exposure. Moreover, even after 5 min of exposure to ultrasonic irradiation (1200 W input power, 28 kHz) the microcystin concentration in EGA suspensions did not increase. For the same input power (120 W), a lower frequency (28 kHz) was found to be more effective in decreasing the photosynthetic activity of EGA than a higher frequency (100 kHz). The sonicated cells did not proliferate when they were cultured in conditions that simulated the bottom of water bodies (i.e. with limited light (400 lx) or no light and non-aerated or aerated (l 1 min(-1))). Furthermore, ultrasonic irradiation did not only collapse gas vacuoles and precipitate EGA, but may have also inflicted damage on the photosynthetic system of the EGA.

Lee, T. J., K. Nakano, et al. (2001). A novel strategy for cyanobacterial bloom control by ultrasonic irradiation. 2nd World Water Congress of the International-Water-Association, Berlin, Germany.

The application of ultrasonic irradiation to control cyanobacterial blooms was evaluated in actual eutrophic lake water. Ten prototype units of the Ultrasonic Irradiation System (USIS) were installed in the 32 ha Lake Senba, and the water and sediment quality were monitored for 2 years. By incorporating the ultrasonication process with the on-going strategy, particularly flushing with induction water, cyanobacterial blooms can be controlled effectively. In addition, a significant improvement in the conditions of the lake in terms of chlorophyll-a, COD and T-P was attained. Moreover, the feasibility of ultrasonic irradiation and bacterial assisted control of cyanobacterial blooms was also evaluated in laboratory conditions. The destruction of gas vacuoles brought about by ultrasonic irradiation promoted close contact between cyanobacteria and their lysing Myxobacter leading to immediate and accelerated destruction of the cells.

Nakano, K., T. F. Lee, et al. (2001). "In situ algal bloom control by the integration of ultrasonic radiation and jet circulation to flushing." Environmental Science & Technology **35**(24): 4941-4946.

A novel strategy for in situ water bloom control was applied and evaluated in Lake Senba. The proposed strategy was to integrate ultrasonic radiation and water jet circulation to an existing flushing process for reducing the growth rate of cyanobacteria and to support the flushing process by providing efficient mixing. Ten units of the system, each consisting of an ultrasonication module and a water jet circulator module, were strategically situated on the lake, and the performance was monitored for 2 years.

Water bloom occurrence reflected as chlorophyll a, SS, and transparency were controlled to lower levels when the integrated system was coupled with sufficient inflow water supply to achieve the target flushing rate. Also, an improvement in the water quality such as COD and phosphorus were observed. Based on linear regression analysis, relationships between water quality parameters and inflow water volume were discussed to evaluate the proposed strategy. Of the three major water quality parameters associated with water bloom, the integrated system contributed mainly to the reduction in SS and transparency compared to chlorophyll a reduction. Improved chlorophyll a reduction may be achieved by strategies that augment effective washout of cyanobacteria during flushing.

Bosma, R., W. A. van Spronsen, et al. (2002). Ultrasound, a new separation technique to harvest microalgae. 9th International Conference on Applied Algology, Aguadulce, Spain, Kluwer Academic Publ.

In this article it is proven that ultrasound can be used to harvest microalgae. The separation process is based on gentle acoustically induced aggregation followed by enhanced sedimentation. In this paper, the efficiency of harvesting and the concentration factor of the ingoing biomass concentration are optimized and the relevance of this process compared to other harvesting processes is determined. For the optimisation, five parameters were modeled simultaneously by the use of an experimental design. An experimental design was chosen, because of possible interaction effects between the different parameters. The efficiency of the process was modeled with a R-squared of 0.88. The ingoing flow rate and the biomass concentration had a lot of influence on the efficiency of the process. Efficiencies higher than 90% were reached at high biomass concentrations and flow rates of 4-6 L day(-1). At most, 92% of the organisms could be harvested and a concentration factor of 11 could be achieved at these settings. It was not possible to harvest this microalga with higher efficiencies due to its small size and its small density difference with water. The concentration factor of the process was modeled with a R-squared of 0.75. The ingoing flow rate, biomass concentration and ratio between harvest flow and ingoing flow rate had a significant effect on the concentration factor. Highest concentration factors, up to 20, could be reached at low biomass concentrations and low harvest flows. On industrial scale, centrifuges can better be used to harvest microalgae, because of lower power consumption, better efficiencies and higher concentration factors. On lab- or pilot-plant scale, an ultrasonic harvesting process has the advantages that it can be operated continuously, it evokes no shear stress and the occupation space is very small. Also, when the algae excrete a soluble high valued product this system can be used as a biofilter.

Segebarth, N., O. Eulaerts, et al. (2002). "Correlation between acoustic cavitation noise, bubble population, and sonochemistry." Journal of Physical Chemistry B **106**(35): 9181-9190.

Quantitative studies of the correlation between sonochemical activity and acoustical noise spectra have been performed. The width of the second harmonic (fwhm2) of the acoustical signal in the frequency domain shows a sensitive dependence to the presence of small amounts (mM range) of an anionic, surfactant in water. This sensitive dependence is also observed for other characteristics of the cavitation noise spectrum and in the sonochemical production of peroxides and correlates well with the sonoluminescence intensity observed by other researchers. Analysis of the experimental data shows that SDS probably modifies the coalescence phenomena.

Ahn, C. Y., M. H. Park, et al. (2003). "Growth inhibition of cyanobacteria by ultrasonic radiation: Laboratory and enclosure studies." Environmental Science & Technology **37**(13): 3031-3037.

The growth of Microcystis aeruginosa UTEX 2388 was repressed by ultrasonic radiation and resulted in an increased chlorophyll a content and cell size, suggesting the inhibition of cell division. However, growth was recovered immediately after the interruption of ultra sonication. In addition to the disruption of gas vesicles, other mechanisms of growth inhibition were also investigated. Although free radicals were produced by ultrasonication and hydrogen peroxide, the resulting lipid peroxidation in the cells was not comparable, indicating minimal damage by the free radicals. Ultrasonic radiation late in the day was found to be most effective in reducing the growth rate of M. aeruginosa, and this timing also corresponded to the phase of daily cell division. In an enclosure experiment, ultrasonic radiation reduced the pH, DO, total nitrogen, and total phosphorus, whereas it increased the water temperature, conductivity, and orthophosphate concentration. The algal cell density and chlorophyll a concentration drastically decreased after 3 d of ultrasonication, plus the cyanobacterial proportion was selectively reduced as compared to other algal species. Accordingly, ultrasonic radiation would appear to have considerable potential as an effective control method for cyanobacterial blooms.

Duckhouse, H., T. J. Mason, et al. (2003). The effect of sonication on microbial disinfection using hypochlorite. 4th Conference on the Applications of Power Ultrasound in Physical and Chemical Processing, Besancon, FRANCE, Elsevier Science Bv.

Ultrasound alone is capable of killing bacteria when sufficient power is applied but ultrasound at low powers can also be used to improve the effectiveness biocides. In this paper, we explore the effect of the timing of the ultrasonic treatment at 20 and 850 kHz on the biocidal efficiency of sodium hypochlorite solution towards Escherchia coli suspensions. A remarkable frequency effect has been noted. At the lower frequency of 20 kHz the improvement in biocidal activity is greatest when the ultrasound is applied at the same time as the hypochlorite. At the higher frequency of 850 kHz the improvement is best when ultrasound is used as a pre-

treatment immediately followed by hypochlorite addition under normal (silent) conditions. The kill rate achieved for pre-treatment using 850 kHz and simultaneous treatment using 20 kHz are very similar. However the former involves less acoustic energy and so is considered to be the more efficient. (C) 2004 Elsevier B.V. All rights reserved.

Tang, J. W., Q. Y. Wu, et al. (2003). "Growth inhibition of the cyanobacterium Spirulina (Arthrospira) platensis by 1.7 MHz ultrasonic irradiation." Journal of Applied Phycology **15**(1): 37-43.

Ultrasonic waves of high frequency (1.7 MHz) and low intensity (0.6 W cm(-2)) were employed to prevent cyanobacterial cells from growing fast and the effects of this growth inhibition were investigated. At least five minutes of ultrasonic irradiation was essential for effective inhibition. The growth rate of irradiated cells was reduced to 38.9% of the control during short-term culture. Longer exposure did not significantly enhance the inhibition. For a particular level of energy input, distributed ultrasonic exposure (more short intermittent exposures) was more effective in inhibiting growth than fewer, but longer exposures. For instance, the final biomass decreased to 30.1% of the control after ultrasonic irradiation for 4 minutes every 3 days, whereas it only decreased to 60% of the control with exposure for 12 minutes every 11 days. It is suggested that distributed ultrasonic irradiation is a practical method to prevent cyanobacterial cells from fast growth. A possible explanation for the inhibition is discussed in relation to cell structure, the absorption spectrum of intact cells, chlorophyll level and oxygen evolution.

Hao, H. W., M. S. Wu, et al. (2004). "Cyanobacterial bloom control by ultrasonic irradiation at 20 kHz and 1.7 MHz." Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering **39**(6): 1435-1446.

Ultrasonic irradiations at high frequency of 1.7 MHz and low frequency of 20 kHz were tested to prevent cyanobacteria Spirulina platensis from bloom. The inhibition effectiveness at 1.7 MHz was much greater than that at 20 kHz. The cyanobacterial biomass was reduced by 63% after 5 min ultrasonic irradiation at 1.7 MHz, whereas three days were needed for the tested cyanobacteria to recover its original density. However, longer exposure time did not significantly enhance the inhibition. It was observed after ultrasonic irradiation that the gas vesicles in cells collapsed, which may result in cyanobacterial precipitation and photosynthetic inhibition. The concentration of chlorophyll a (Chla) was reduced and its biosynthesis was delayed in a 4-day continuous culture. The fluorescence spectra at 77K of phycobilisome (PBS) and absorption spectra of intact cells in vivo showed that light energy transfer in PBS was inhibited and phycocyanin (PC) was damaged much more acutely compared with Chla. These results indicated that 5 min ultrasonic irradiation at 1.7 MHz every third day might be an effective and economic operation mode for practical application.

Hao, H. W., M. S. Wu, et al. (2004). "Cavitation mechanism in cyanobacterial growth inhibition by ultrasonic irradiation." Colloids and Surfaces B-Biointerfaces **33**(3-4): 151-156.

To prevent cyanobacterial bloom in eutrophic water by ultrasonic method, ultrasonic irradiations with different parameters were tested to inhibit Spirulina platensis from growth. The experimental result based on cyanobacterial growth, chlorophyll a and photosynthetic activity showed that, the ultrasonic irradiation inhibited cyanobacterial proliferation effectively, furthermore the inhibition effectiveness increased in the order: 200 kHz > 1.7 MHz > 20 kHz and became saturated with the increased power. The inhibition mechanism can be mainly attributed to the mechanical damage to the cell structures caused by ultrasonic cavitation, which was confirmed by light microscopy and differential interference microscopy. The optimal frequency of 200 kHz in cavition and sonochemistry was also most effective in cyanobacterial growth inhibition. The higher frequency of 1.7 MHz is weaker than 20 kHz in cavitation, but has more effective inhibition because it is nearer to the resonance frequency of gas vesicle. The inhibition saturation with ultrasonic power was due to the ultrasonic attenuation induced by the acoustic shielding of bubbles enclosing the radiate surface of transducer.

Svrcek, C. and D. W. Smith (2004). "Cyanobacteria toxins and the current state of knowledge on water treatment options: a review." Journal of Environmental Engineering and Science **3**(3): 155-185.

Cyanobacteria toxins have quickly risen in infamy as important water contaminants that threaten human health. This paper provides a broad overview of cyanobacteria toxins and the current state of knowledge about water treatment options to reduce these toxins. The first part of the paper focuses on cyanobacteria as organisms and their ability to produce a variety of toxins, the proposed or accepted regulatory guidelines for these toxins, and common detection techniques. Then a review is presented of the past 25 years worth of work on cyanobacteria toxin removal using both conventional and advanced water treatment processes and operations. The paper concludes by identifying directions for future research required to advance the abilities of utilities and water treatment plant designers to deal with these toxins while long-term, watershed management and surveillance plans are developed and implemented. As well, some suggestions are provided for immediate steps that a water utility facing cyanobacteria blooms could take to minimize human exposure to these toxins.

Tang, J. W., Q. Y. Wu, et al. (2004). "Effect of 1.7 MHz ultrasound on a gas-vacuolate cyanobacterium and a gas-vacuole negative cyanobacterium." Colloids and Surfaces B-Biointerfaces **36**(2): 115-121.

Ultrasonic signals propagated through medium were directly applied to unicellular cyanobacterium cell surfaces to investigate the biological

effects induced by ultrasound. The gas-vacuolate cyanobacterium Microcystis aeruginosa and the gas-vacuole negative cyanobacterium Synechococcus PCC 7942 responded differently to ultrasound. When M. aeruginoso was irradiated by 1.7 MHz ultrasound at 0.6 W cm(-2) every day, it showed a decrease of nearly 65% in biomass increment, and this group's generation time increased twice as much as the control. While Synechococcus culture irradiated every day still grew as fast as the control, and its final biomass was as much as the control. The value of the electric conductivity change (Deltasigma) sharply increased in Microcystis suspension during the exposure process, which revealed more ultrasonic cavitation yield in liquid related to the gas-vacuolate cyanobacteria. The relative malondialdehyde (MDA) content, a quantitative indicator of lipid peroxidation, increased by 65% in Microcystis cells and 9% in Synechoccus cells after ultrasonic irradiation. Moreover, the membrane permeability, quantified by measuring the relative amount of electrolyte leaking out of cells, increased to more than 60% in the Microcystis cells. The results indicated that Microcystis cells were susceptible to ultrasonic stress. According to Rayleigh-Plesset's bubble activation theory, 1.7 MHz ultrasound approached the eigenfrequency of gas-vacuolate cells. The present investigation suggested the importance of the cavitational effect relative to intracellular gas-vacuoles in the loss of cell viability. In summary, 1.7 MHz ultrasonic irradiation was effective in preventing water-bloom forming cyanobacteria from growing rapidly due to changes in the functioning and integrity of cellular and subcellular structures. (C) 2004 Elsevier B.V. All rights reserved.

Zhang, G. M., B. Wang, et al. (2004). Removal of algae by sonication-coagulation. 4th International Conferene Watershed Management, Shenzhen, PEOPLES R CHINA.

Algae bloom in source water has caused serious problems in drinking water supplies, and conventional methods for its treatment have achieved only limited success. This paper reports a new technology, ultrasound assisted coagulation, for effective removal of algae cells from the source water in water treatment works. The results showed that ultrasonic pretreatment significantly enhanced the removal efficiency of algae cells. Ultrasonic irradiation for 5 s increased the algae removal efficiency by more than 20% when the coagulant dose was 0.4-0.8 mg/L. To achieve the same algae removal ratio of 90%, sonication for 5 s reduced the coagulant dose by 2/3. The optimal sonication parameters were determined as follows: sonication time of 1 s, ultrasonic power of 48 W, and solution pH of 8-9. The sound frequency had little impact on the algal removal efficiency. Ultrasonic pretreatment also significantly reduced the sample turbidity.

Ma, B. Z., Y. F. Chen, et al. (2005). "Influence of ultrasonic field on microcystins produced by bloom-forming algae." Colloids and Surfaces B-Biointerfaces **41**(2-3): 197-201.

Under the background of algae removal and growth inhibition by ultrasonic irradiation, the effects of ultrasonic irradiation on removal of Microcystis, the concentration variation of microcystins (MC) produced by Microcystis in Microcystis suspension, and sonochemical degradation of microcystins in water, were studied in the paper. The results showed that ultrasonic irradiation could efficiently inhibit the growth of Microcystis. and ultrasonic irradiation shorter than 5 min would not introduce the increase of microcystins dissolved in Microcystis suspension simultaneity. Also, microcystins dissolved in Microcystis suspension would not increase as ultrasonic power increasing. Further research showed that microcystins were effectively degraded in ultrasonic fields. After 20 min ultrasonic irradiation at 150 kHz and 30 W, the removal rate of microcystins reached 70%. (c) 2004 Elsevier B.V. All rights reserved.

Mason, T. J. (2005). Developments in ultrasound - Non-medical. Workshop on the Effects of Ultrasound and Infrasound Relevant to Human Health, Chilton, ENGLAND, Pergamon-Elsevier Science Ltd.

Ultrasound is defined as sound of a frequency that is too high for the human ear to detect-i.e. it is inaudible. Nevertheless this "silent sound" has a large range of applications in science, medicine and industry. The study of the effects of ultrasound on materials-known as sonochemistry-is one of the broadest and most exciting areas in current research. In this review some recent developments with major potential are identified from the fields environmental protection and materials processing. Environmental protection can refer to methods of preventing pollution or to the removal of existing pollution. Here we will look at examples drawn from the latter in which ultrasound has been used for the purification of water (chemical and biological), the decontamination of the atmosphere and soil remediation i.e. the classic three domains of water, air and land. In terms of materials processing two examples have been chosen, the treatment of sewage sludge and the control of crystallisation. In both of these cases it is predominantly the mechanical effects of acoustic cavitation, which produce the enhanced digestion, and dewatering of sludge and provide for the control in crystallisation processes. (c) 2006 Elsevier Ltd. All rights reserved.

Postema, M., A. Bouakaz, et al. (2005). "Ultrasound-induced gas release from contrast agent microbubbles." Ieee Transactions on Ultrasonics Ferroelectrics and Frequency Control **52**(6): 1035-1041.

We investigated gas release from two hard-shelled ultrasound contrast agents by subjecting them to high-mechanical index (MI) ultrasound and simultaneously capturing high-speed photographs. At an insonifying frequency of 1.7 MHz, a larger percentage of contrast bubbles is seen to crack than at 0.5 MHz. Most of the released gas bubbles have equilibrium diameters between 1.25 and 1.75 mu m. Their disappearance was observed optically. Free gas bubbles have equilibrium diameters smaller than the bubbles from which they have been released. Coalescence may account for the long dissolution times acoustically observed and published in previous studies. After sonic cracking, the cracked bubbles stay acoustically active.

Rapuntean, G., N. Fit, et al. (2005). Ultrasounds action on microorganisms in normal culture conditions. Symposium on Prospects of the Agriculture of the 3rd Millenium Science, Cluj Napoca, ROMANIA, Academic Press.

Ultrasounds generators have a wide applicability in biology and medicine, being used for disintegrating various cell types. In microbiology and immunology, the microbial cells' disruption is realized especially for obtaining antigens, used in diagnosis or as antigen masses in vaccines production. The ultrasonic disintegrator DUS P 150 (INCDFT Iasi) was used in our research, at 21-22 kHz and two acoustic power levels: level 1 (80 V.A.), and level 2 (150 V.A.). Microorganisms strains from Escherichia, Salmonella, Bordetella, Listeria, Erysipelothrix, Staphylococcus, Mycobacterium, Malassezia, Candida, and Prototheca genera were exposed to ultrasounds. The destructive effect was correlated with the exposure time and was more intense at the level 2 power (150 V.A.). The destructive capacity and its intensity were determined by bacterioscopical exams (smears), in order to observe the induced morphological alterations, and by bacteriological exams (culture media inseminations), in order to determine the viability of the not destructed cells. The Gram positive bacteria, the yeasts, and the unicellular algae were more sensitive than the Gram negative bacteria.

Zinin, P. V., J. S. Allen, et al. (2005). "Mechanical resonances of bacteria cells." Physical Review E **72**(6): 10.

The quality of the natural vibrations of specific bacteria is investigated using a shell model which accounts for the elastic properties of the membrane and the associated viscosities of the cytoplasma and the surrounding fluid. The motion of the membrane is approximated in terms of the distribution of internal forces over the shell thickness, which is assumed to be much less than the size of the cell. Flexural moments and intersecting stresses are neglected. Using experimentally obtained values for the membrane properties, high-quality resonances are predicted for several types of bacteria which have radii greater than 5 mu m. Viscous shear waves are the main source of energy dissipation as has been previously reported in other studies on the natural oscillations of red blood cells, drops, and bubbles. Implications for the acoustic mediated destruction of bacteria are discussed.

Dehghani, M. H. and F. Changani (2006). "The effect of acoustic cavitation on chlorophyceae from effluent of wastewater treatment plant." Environmental Technology **27**(9): 963-968.

The Chlorophyceae are a large and important group of green algae. They include some of the most common species, as well as many members that are important both ecologically and scientifically. When abundant in the water, they can rapidly cover the surface of sand filters and drastically

reduce the length of filter runs. Also, tastes and odors are caused by the release of certain compounds by both living algae and dead and decomposing algae. This study will provide basic information on the fundamentals of acoustic cavitation as a new technology for control of Chlorophyceae growth. This technology is an attractive means to improve water quality because of the simplicity of the system and no production of toxic by-products. The inactivation of Chlorophyceae is mainly due to cavitation. Cavitation is a primary mechanism of ultrasound waves that occurs when the gas vesicles are acted upon by sufficiently intense ultrasound waves of different frequencies. Waves collapse gas vacuoles and precipitate Chlorophyceae. Also damage is inflicted on the chlorophyll of Chlorophyceae. Experiments have been carried out using ultrasound reactor in a laboratory pilot plant, to investigate the effect of acoustic cavitation. The results show that increasing the short exposure to waves has a considerable effect on destruction of Chlorophyceae growth and results in the loss of buoyancy. At 42 kHz it is shown that 100% of the Chlorophyceae can be destroyed in 130 seconds.

Zhang, G. M., P. Y. Zhang, et al. (2006). "Ultrasonic damages on cyanobacterial photosynthesis." Ultrasonics Sonochemistry **13**(6): 501-505.

Excessive cyanobacterial growth in eutrophic water sources has been a serious environmental problem, and both sight preservation and drinking water production demand control of cyanobacterial growth in water. Ultrasonic treatment was reported to effectively inhibit cyanobacterial growth through vesicle collapsing and cell fracturing, but little was known about the change of cyanobacterial photosynthesis during sonication. This paper examined the ultrasonic inhibition of Microcystis aeruginosa cell growth and extracellular microcystins release, and the instant ultrasonic decreases of antenna complexes like cyanobacterial chlorophyll a and phycocyanins (PC), and the oxygen evolution rate. The results showed that sonication effectively damaged antenna complexes, slowed down the photo-activity, which significantly inhibited the cell growth and microcystins formation and release. (C) 2005 Elsevier B.V. All rights reserved.

Zhang, G. M., P. Y. Zhang, et al. (2006). "Ultrasonic frequency effects on the removal of Microcystis aeruginosa." Ultrasonics Sonochemistry **13**(5): 446-450.

Algae bloom in source water causes high chemical consumption and deteriorates water quality in waterworks. This paper studied the ultrasonic removal of Microcystis aeruginosa. The results showed that algae cells could be effectively removed by sonication and gas vesicle collapse was the main mechanism. The ultrasonic algae removal followed the first order reaction with a rate constant of 0.023 min(-1) (80 W, 80 kHz). Higher ultrasound frequency benefited algae removal; the algae removal rate constant was 0.114 min(-1) at 1320 kHz and 0.0224min(-1) at 20 kHz (80W). Higher ultrasound power also accelerated algae removal; the algae removal rate constant was 0.023 min(-1) at 80 W and 0.007 min(-1) at 32 W (80 kHz). However, high ultrasound power and long irradiation caused

microcystins to increase. 80 W, 80 kHz sonication for 5 min increased the extracellular microcystins concentration from 0.87 mu g/L to 3.11 mu g/L. Sound frequency had little impact on the microcystins release. The chlorophyll a concentration initially decreased and then stabilized after 5 min of sonication. (c) 2005 Elsevier B.V. All rights reserved.

Ahn, C. Y., S. H. Joung, et al. (2007). "Selective control of cyanobacteria in eutrophic pond by a combined device of ultrasonication and water pumps." Environmental Technology **28**(4): 371-379.

A combined device consisting of an ultrasonic apparatus and water pumps was operated in a eutrophic pond to study its effect on the control of cyanobacteria as compared with those of a non-treated, neighboring pond. The combined apparatus seemed to be enough to spread the sonicated water to the whole surface of a 9,000 m(3) pond. Although the high rainfall in 2003 resulted in an overall dominance of diatoms, cyanobacterial growth was significantly inhibited by the apparatus in the treated pond. In addition, the chlorophyll-a concentration and total algae in the treated pond were 61 and 53%, respectively, of the levels in the control pond. The reduced algal growth (7% of the control) by the combined apparatus was mainly due to,he inhibition on the growth of cyanobacteria. The cyanobacterial proportion in the treated pond, however, increased significantly for several days, when the apparatus was stopped. Meanwhile, the proportion of green algae increased in the treated pond. The successful selective control of cyanobacteria using the combined apparatus suggests that ultrasonication can be a practical method to control bloom and toxin production in eutrophic waters.

Kobayashi, N., T. W. Bauer, et al. (2007). "Brief ultrasonication improves detection of biofilm-formative bacteria around a metal implant." Clinical Orthopaedics and Related Research(457): 210-213.

Biofilms are complex microenvironments produced by microorganisms on surfaces. Ultrasonication disrupts biofilms and may make the microorganism or its DNA available for detection. We determined whether ultrasonication could affect our ability to detect bacteria adherent to a metal substrate. A biofilm-formative Staphylococcus aureus strain was used for an in vitro implant infection model (biofilm-formative condition). We used quantitative culture and real time-polymerase chain reaction to determine the influence of different durations of ultrasound on bacterial adherence and viability. Sonication for 1 minute increased the yield of bacteria. Sonication longer than 5 minutes led to fewer bacterial colonies by conventional culture but not by polymerase chain reaction. This suggests short periods of sonication help release bacteria from the metal substrate by disrupting the biofilm, but longer periods of sonication lyse bacteria prohibiting their detection in microbiologic cultures. A relatively short duration of sonication may be desirable for maximizing detection of biofilm-formative bacteria around implants by culture or polymerase chain reaction.

Wu, M. Y. and J. Wu (2007). "In-vitro investigations on ultrasonic control of water chestnut." Journal of Aquatic Plant Management **45**: 76-83.

Water chestnut (Trapa natans L.) is native to southern Europe and tropical Africa and Asia and was first introduced into North America in 1874. Since then, wild populations have quickly become established in many locations in the northeastern United States. T natans is referred to as a noxious aquatic weed since its aggressive growth usually results in complete coverage of the water surface with floating rosettes of leaves. This study investigated the potential of the ultrasonic control of water chestnut since ultrasound has been documented to effectively damage plant cells and tissues. Various frequencies and amplitudes of ultrasound waves generated by submerged transducers were applied directly to water chestnuts. Ultrasound frequencies of 20-kHz, 100-kHz, 500-kHz, 1-MHz, and 2-MHz caused substantial damage to plant cells and penetrated petiole tissues. 20-kHz ultrasound caused the most significant cell damage after 10 seconds of ultrasound exposure. The mortality rate of water chestnut plants treated with ultrasound aimed directly at water chestnut stems was 97% with no seed production. The results of this laboratory study demonstrated that ultrasound caused severe damage and plant death by aiming 20-kHz ultrasound waves directly on water chestnut stems. In the future, development of a high-efficiency multi-transducer device is recommended for a field demonstration. Limited research has been conducted to determine the effects of 20-kHz ultrasound on benthic organisms, fish or wildlife, and therefore additional studies should be conducted to investigate potential impacts of ultrasound on aquatic communities prior to large-scale field application.

Jiranek, V., P. Grbin, et al. (2008). "High power ultrasonics as a novel tool offering new opportunities for managing wine microbiology." Biotechnology Letters **30**(1): 1-6.

Industrial scale food and beverage processes that utilize microorganisms are typically faced with issues related to the exclusion, suppression or elimination of spoilage organisms. Yet the use of traditional anti-microbial treatments such as heat, chemical biocides or sterile filtration may themselves be restricted by regulations or else be undesirable due to their adverse sensory impacts on the product. High power ultrasound (HPU) is a technology whose application has been evaluated if not exploited in several food and beverage processes but has yet to be introduced into the wine industry. This review examines the research findings from related industries and highlights possible applications and likely benefits of the use of HPU in winemaking.

Joyce, E. M. and T. J. Mason (2008). "Sonication used as a biocide A review: Ultrasound a greener alternative to chemical biocides?" Chimica Oggi-Chemistry Today **26**(6): 22-+.

Today there are increasing levels of environmental pollution and there is evidence for the growing resistance of bacteria to traditional biocides. When these two factors are coupled to the rising cost of and concern about the possible overuse of biocides it is not surprising that there is active research underway to find new or improved biocidal treatments. Ultrasound offers the possibility of a green cost effective technology for the future in that, under the right conditions, it is capable of inactivating waterborne bacteria either alone or in combination with other technologies. Ultrasound induces acoustic cavitation in a medium and in turn this produces high shear forces and radical species both of which are harmful to bacteria.

Kotopoulis, S., A. Schommartz, et al. (2008). Sonic cracking of blue-green algae. Special Session on Bubbles and Ultrasound held at the IOA 2008 Spring Conference, Reading, ENGLAND, Elsevier Sci Ltd.

Algae are aquatic organisms classified separately from plants. They are known to cause many hazards to humans and the environment. Algae strands contain nitrogen-producing cells that help them float (heterocysts). It is hypothesized that if the membranes of these cells are disrupted by means of ultrasound, the gas may be released analogous to sonic cracking, causing the strands to sink. This is a desirable ecological effect, because of the resulting suppressed release of toxins into the water. We subjected small quantities of blue-green algae of the Anabaena sphaerica species to ultrasound of frequencies and pressures in the clinical diagnostic range, and observed the changes in brightness of these solutions over time. Blue-green algae were forced to sink at any ultrasonic frequency we studied, supporting our hypothesis that heterocysts release nitrogen under ultrasound insonification in the clinical diagnostic range. Although the acoustic fields we used to eradicate blue-green algae are perfectly safe in terms of mechanical index, the acoustic pressures surpass the NURC Rules and Procedures by over 35 dB. Therefore, caution should be taken when using these techniques in a surrounding where aquatic or semi-aquatic animals are present. (C) 2009 Elsevier Ltd. All rights reserved.

Kotopoulis, S., A. Schommartz, et al. (2008). Safety Radius for Algae Eradication at 200 kHz-2.5 MHz. IEEE Ultrasonics Symposium, Beijing, PEOPLES R CHINA.

Algae have been proven to be a severe health hazard to humans, aquatic and semi-aquatic animals. Chemical methods available to control the algae have unwanted side-effects. For this reason, ultrasonic algae control has been under investigation. We measured the eradication effectiveness of ultrasound at three typical centre frequencies. At all three frequencies physical damage to the algae was observed. We conclude that it is possible to eradicate blue-green algae in the clinical diagnostic range. Taking into account the geometry, the low attenuation in water, and the NATO Undersea Research Centre for Human Diver and Marine Mammal Risk Mitigation Rules and Procedures, even at these low voltages, the safe swimming distance is at least several meters away from the sound source.

Shi, H. X., J. H. Qu, et al. (2008). "Effect of ultrasonic irradiation on the coagulation and inactivation of Microcystis." Journal of Water Supply Research and Technology-Aqua **57**(2): 101-108.

The effectiveness of ultrasonic irradiation on coagulation and inactivity of algal cells was evaluated in the laboratory. Experiments were carried out under different conditions with or without ultrasound using polyaluminium hydroxychloride (PACl) as coagulant and Microcystis as test species. The results suggested that ultrasonic irradiation increased cells' inactivity and obviously improved the coagulation process of algal cells. An increased rate of coagulation and reduced dosage of PACl required to cause efficient flocculation for algae removal were observed in coagulation experiments with ultrasound irradiation. At the same time, compared with samples without irradiation, the characteristics of flocs were improved and the settling rate was increased greatly. A very short period of ultrasonic pretreatment with 40W input power was enough to achieve substantial removal efficiency under the condition that there was no breakage in algal cells. The changes of growth curves for algal samples during the seven days' culturing suggested that ultrasound was effective for the inactivation of the test algae. The possible mechanisms for the enhanced effects on the coagulation and inactivity of Microcystis were that ultrasonic irradiation changed internal and external characteristics of algal cells, which co-promoted their immediate and accelerated coagulation and settlement.

Gibson, J. H., H. Hon, et al. (2009). "Effects of ultrasound on suspended particles in municipal wastewater." Water Research **43**(8): 2251-2259.

The objective of this research is to explore the fundamental characteristics of how particles in wastewater respond to ultrasound, with an aim to improve wastewater disinfection. Particles of a predetermined size fraction and concentration were treated with varying doses of ultrasound at 20.3 kHz. Ultrasonic power transfer to the fluid was measured using calorimetry or acoustical measurements. Image analysis particle counting was used to measure the size distribution of particles before and after ultrasound treatment. The influence of three parameters: particle origin (raw wastewater or from the aeration basin of the activated sludge process), particle concentration, and particle size on the percentage of particle breakage after ultrasound treatment was compared. it was found that raw wastewater and aeration basin particles of the same size fraction (90-106 mu m) responded to ultrasound in a similar way. Particle breakage was not affected by changes in particle concentration from 100 to 400 particles per mL. Larger wastewater particles (90-250 mu m) were more susceptible to breakage than smaller ones (38-63 mu m diameter). The percentage of particle breakage increased linearly with a logarithmic increase in the ultrasound energy density, that is the ultrasound energy delivered per unit volume of the sample (R-2 = 0.48-0.91). An expression that predicts the percent of particles broken as a function of ultrasound energy density is provided. Crown Copyright (C) 2009 Published by Elsevier Ltd. All rights

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Koda, S., M. Miyamoto, et al. (2009). "Inactivation of Escherichia coli and Streptococcus mutans by ultrasound at 500 kHz." Ultrasonics Sonochemistry **16**(5): 655-659.

This paper shows a systematic study of the 500 kHz frequency ultrasound efficiency on the microbial inactivation as a function of ultrasonic power delivered into the bacterial suspension. The inactivation of Escherichia coli IAM 12058, a Gram-negative bacterium and Streptococcus mutans JCM 5175, a Gram-positive bacterium is enhanced by increasing the ultrasonic power in the range of 1.7-12.4 W and the logarithm of survival ratio decreases linearly with irradiation time, except for E. coli sonicated with the highest power level. The rate constants were estimated in the linear region of the plots representing survival ratio logarithm vs. sonication time. A better understanding of the inactivation process at 500 kHz could be gained by suppressing the chemical effects with a radical scavenger. We find out that the rate constants increase with the ultrasonic power delivered into the solution and dramatically decrease by the addition of t-butanol as a radical scavenger to the bacterial suspension. For comparison, experiments were carried out at a low frequency level of 20 kHz. It was found out that for the same ultrasonic power delivered into the bacterial suspension, the inactivation was slightly enhanced at 500 kHz frequency. The examinations of bacterium performed with a TEM revealed lethal damages arising from the interaction of bacterial cells with the cavitational bubbles. A significant amount of empty cell envelopes as well as their cytoplasmatic content was detected. Thus, based on these new data, the mechanism of bacterial inactivation by ultrasounds at high frequency is discussed here. (C) 2009 Elsevier B.V. All rights reserved.

Liang, H., J. Nan, et al. (2009). "Algae removal by ultrasonic irradiation-coagulation." Desalination **239**(1-3): 191-197.

The effectiveness of ultrasonic irradiation on algae removal by coagulation was studied. Laboratory results suggest that ultrasonic treatment at 40 kHz and 60W for 15 s can improve algae coagulation removal by 12.4% as compared with direct coagulation. A photometric dispersion analyzer was employed to monitor the algae coagulation in this study. It is also indicated that variation in ultrasonic frequency does not have a notable effect on algae removal while increasing ultrasonic power to more than 60W produces a negative result. The optimal irradiation duration is determined as 15 s. In conclusion, ultrasonic irradiation-coagulation proves effective for algae removal. However, practical application still takes time due to certain limitations of the technique.

Mahvi, A. H. (2009). "Application of Ultrasonic Technology for Water and Wastewater Treatment." Iranian Journal of Public Health **38**(2): 1-17.

Ultrasonic technology as an innovative technology may be used for water and wastewater treatment for pollution removal. This technology acts as an advanced oxidation process. Application of this technology leads to the decomposition of many complex organic compounds to much simpler compounds during physical and chemical compounds during cavitation process. In this article review, some applications of this valuable technology are presented.

Monsen, T., E. Lovgren, et al. (2009). "In Vitro Effect of Ultrasound on Bacteria and Suggested Protocol for Sonication and Diagnosis of Prosthetic Infections." Journal of Clinical Microbiology **47**(8): 2496-2501.

Sonication of implants has been shown to be a promising method for diagnosis of prosthetic infections due to its improved sensitivity, simplicity, and low cost. The aim of the present study was to evaluate the effects of ultrasound performed under different conditions regarding temperature, duration, and composition of sonication tubes on bacterial species often associated with prosthetic infections. We found that ultrasound had an inhibitory effect on bacteria, of which gram-negative bacteria, in particular Escherichia coli, were almost eradicated after 5 min of sonication at 35 degrees C. Gram-positive bacteria were found to be resistant to the effect of ultrasound. Four factors were important for the inhibitory effect of sonication: the type of microorganism, the temperature of the sonication buffer, the duration of exposure to ultrasound (minutes), and the material and composition of the sonication tube in which sonication is performed. On the basis of the results from the present study, we propose a protocol for sonication and recovery of bacteria associated with biofilm on infected implants prior to conventional culture. From the present protocol, we recommend sonication for 7 min at 22 degrees C at the maximum effect which permits survival of gram-negative bacteria.

Yang, F., X. Q. Li, et al. (2009). Studies on Removal of Microcystis and Microcystins-LR by the Low-Power and Low-Frequency Ultrasonic Irradiation. 8th National Postgraduate Conference on Environmental and Occupational Medicine, Suzhou, PEOPLES R CHINA, Shanghai Ctr Dis Control & Prevention.

[Objective] To reveal the effect of removal of Microcystis and degradation of microcystin-LR by ultrasonic irradiation with low-frequency and low-power and impact factors of ultrasonic algicidal technique. [Methods] Microcystis and microcystin-LR were treated with 3.4 W, 15 W, 29 W, 44 W 20 kHz low-power ultrasound, respectively. And the concentration of Microcystis was detected by spectrophotometry, the concentration of microcystins-LR was detected by HPLC. [Results] Treated by ultrasound,. the concentration of Microcystis of the treatment group was significantly lower than that of the control group. When the samples were exposed, to 20 kHz ultrasound with different powers of 15 W, 29 W, 34 W and 44 W for 600 s, the instantaneous algae removal rates were 4%, 17%, 23% and 34%, the highest removal rates of Microcystis were 43%, 90%, 93% and 88% during the next five days. When the ultrasound of 20 kHz and 44 W was applied with 15 s, 60 s, 240 s and 600 s, the instantaneous removal rates of Microcystis were 3%; 6%, 16% and 31%. The highest removal rates of

Microcystis were 78%, 87%, 86% and 87% during the next four days. With the treatment of ultrasound of 20 kHz and 44 W, the degradation of microcystin-LR was founded. [Conclusion] Ultrasound with low-frequency and low-power can degrade Microcystis and microcystins-LR: The optimal parameters of ultrasound were 44 W, 20 kHz and 60 seconds.

Zhang, G. M., P. Y. Zhang, et al. (2009). "Ultrasound-enhanced coagulation for Microcystis aeruginosa removal." Ultrasonics Sonochemistry **16**(3): 334-338.

Source water eutrophication has caused serious problems in drinking water supplies, with enhanced coagulation widely used to remove the resulting algae. This paper investigates the use of sonication to improve the removal by coagulation of Microcystis aeruginosa, a common species of toxic algae. The results show that sonication significantly enhances the reduction of algae cells, solution UV254, and chlorophyll a without increasing the concentration of aqueous microcystins. The main mechanism involved the destruction during ultrasonic irradiation of gas vacuoles inside algae cells that acted as 'nuclei' for acoustic cavitation and collapse during the "bubble crush" period, resulting in the settlement of cyanobacteria. Coagulation efficiency depended strongly on the coagulant dose and sonication conditions. When the coagulant dose was 0.5 mg/l, 5 s of ultrasonic irradiation increased algae removal efficiency from 35% to 67%. As further sonication enhanced the coagulation efficiency only slightly due to mixing, optimal sonication time was 5 s. The most effective sonication intensity was 47.2 W/cm(2), and the highest removal ratio of M. aeruginosa was 93.5% by the sonication-coagulation method. Experiments with reservoir water showed that this method could be successfully applied to natural water multiple species of algae. (c) 2008 Elsevier B.V. All rights reserved.

Zinin, P. V. and J. S. Allen (2009). "Deformation of biological cells in the acoustic field of an oscillating bubble." Physical Review E **79**(2): 12.

In this work we develop a theoretical framework of the interaction of microbubbles with bacteria in the ultrasound field using a shell model of the bacteria, following an approach developed previously [P. V. Zinin et al., Phys. Rev. E 72, 61907 (2005)]. Within the shell model, the motion of the cell in an ultrasonic field is determined by the motion of three components: the internal viscous fluid, a thin elastic shell, and the surrounding viscous fluid. Several conclusions can be drawn from the modeling of sound interaction with a biological cell: (a) the characteristics of a cell's oscillations in an ultrasonic field are determined both by the elastic properties of the shell the viscosities of all components of the system, (b) for dipole quadrupole oscillations the cell's shell deforms due to a change in the shell area this oscillation depends on the surface area modulus K-A, (c) the relative change in the area has a maximum at frequency f(K)similar to 1/2 pi root K-A/(rho a(3)), where a is the cell's radius and rho is its density. It was predicted that deformation of the cell wall at the frequency f(K) is high enough to rupture small bacteria such as E. coli in which the

quality factor of natural vibrations is less than 1 ($Q<1$). For bacteria with high value quality factors ($Q>1$), the area deformation has a strong peak near a resonance frequency f(K); however, the value of the deformation near the resonance frequency is not high enough to produce sufficient mechanical effect. The theoretical framework developed in this work can be extended for describing the deformation of a biological cell under any arbitrary, external periodic force including radiation forces unduced by acoustical (acoustical levitation) or optical waves (optical tweezers).