Ultrasound - A Solution for Algae Control in Water Treatment Plants

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Abstract

The water algal "bloom" is a biological pollution, which is followed by negative effects related to the appearance of algal toxins. According to their chemical composition, algae toxins are complex organic compounds without odour, colour, resistant to sterilization and mostly soluble in water. During the "bloom" periods, the concentration of algae reaches millions of cells / ml, which increases the operating costs in the water treatment plants at the same time as the deterioration of water quality throughout the technological flow. Control of algal growth in treatment plants using surface water for drinking is an essential component of compliance with the quality of water delivered to legal requirements and the optimization of operating costs.

Keywords: algal bloom, algal toxins, drinking water, ultrasound

1. Introduction

Algae are mandatory components of aquatic ecosystems influencing the quality of natural waters. There are more than 30 thousand species of algae, with algal cell lifespans on the order of hours.

Untreated surface waters feeding treatment plants come from natural or artificial reservoirs and are subject to eutrophication and thermal inversion. The significant algal concentration of the source propagates both in the water intakes and in the technological installations - decanters, filters, basins (figure 1 shows algal growth in the decanters of the water treatment plant) causing a whole chain of negative effects with impact on water quality and operating costs.

Particularly dangerous is the "bloom" of blue-green algae (Cyanophyta) in water sources used for drinking [1]. The dying Cyanophyta cells release toxins that can get into the drinking water system. Prolonged exposure to high levels of toxins could have long-term, chronic effects on humans. The first symptoms being: headache, fever, diarrhea, abdominal pain, nausea and vomiting [2,3].

Directive 2184/EU/2020 on the quality of water intended for human consumption includes the monitoring of microcystin LR for potential blooms in the water source (increased cyanobacterial cell density or potential for blooms). Microcystin LR should not exceed 1 µg/l [4].

Figure 1 - Algae Growth in Water Treatment Plants

The precursors of the mass growth of blue-green algae are usually diatoms and green algae. Thus, compared to diatom and green algae, blue-green algae photosynthesize at lower light intensities and use much less energy for breathing in the dark. These algae have a high multiplication potential: within 70 days during the growing season a single cell can produce 10^{20} offspring [5].

The main causes of the occurrence of blue-green algae-conditioned "blooms" are [5]:

- Change in the hydrological regime of rivers - abrupt change in the speed of water flow, formation of stationary slow flow zones
- Thermal regime. Diatom algae prefer low temperatures and usually breed at temperatures below 16°C (spring and autumn). Under certain conditions, diatom algae cause the water to 'bloom'. However, the proportions are incomparable to the 'blooms' due to blue-green algae. These algae prefer higher temperatures; their maximum bloom is observed at 20-30°C. In aquatic pools, intense warming occurs in the shallow sections of the static zones.
- Over-saturation of the pond with nitrogen and phosphorus compounds. Usually phosphorus serves as the limiting biogen, but nitrogen can also be a limiting biogen. The "bloom" burst starts at an N/P ratio ≈ 10[5].

The "bloom" phenomenon has several negative consequences for water quality:

- Appearance of organoleptic changes (colour, taste, smell)
- Biological clogging of the lake, decanters resulting in a reduction of the useful volume due to increased organic matter content at the bottom of the lake/decanter
- Inability to circulate and transform organic matter due to too abundant organic matter
- A drastic reduction in the dissolved oxygen content due to the increased decomposition reactions of organic matter
- Reduced efficiency of coagulant, flocculant and disinfectants used in the water treatment process
- Filter clogging and secondary bacterial growth in the filter layer
- Increased technological water consumption (decanter siphoning, filter washing)
- Increased operating costs
- Deteriorationin the quality of water supply

2. Materials and methods

In order to evaluate the effectiveness of ultrasound in reducing algal concentration, in 2015 an ultrasound device was purchased from LG Sonic-Holland and installed in one of the radial decanters providing the technological flow for drinking water treatment in the Paltinu-Voila-Campina Treatment Plant (belonging to the Prahova Zonal System Operation).

Ultrasound technology controls algal growth by flooding the algal cell with a stream of ultrasound that has a resonant frequency with that of the algal cells, thus influencing the cell structure. Blue-green algae have a gas vesicle system of hundreds to thousands of organelles per cell, which is easily disrupted by ultrasonic sound waves. This causes the algae to lose buoyancy and sink, disrupting their life cycle processes [5].

Moving algae (green, golden, filamentous) do not have gas vesicles, but the ultrasound unit affects the algae's inner cell membrane, causing it to separate from the outer one.

When the separation is complete, the cell can no longer obtain nutrients, control internal pressure, or remove waste via contractile vacuoles [6].

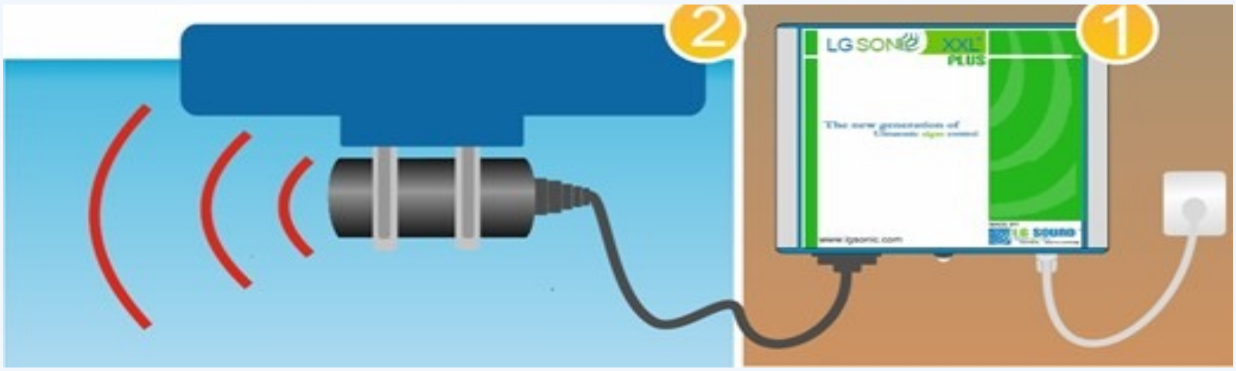


Figure 2- Ultrasonic device type of LG Sonic (1 - controller with 12 different frequency channels, 2- transmitter)

Note that a single transmitter does not cover the entire surface of the decanter, but only about 30-35% of its surface, as shown in Figure 3.

In order to evaluate the effect of this ultrasonic device on the algal concentration, a series of comparative biological analyses of the phytoplankton of the two radial decanters (one with ultrasonic device and one without) was started in May-October 2015.

Phytoplankton samples were collected from the decanter sampling points using the plankton net. The identification of algal species was carried out with the Olympus CX 41 microscope and specific determiners.

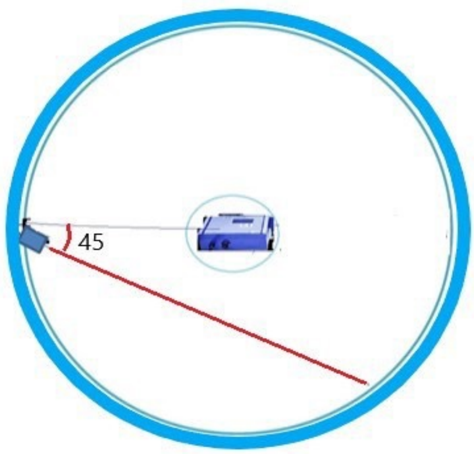


Figure-3- Mounting an LG Sonic transmitter on the radial decanter

3. Results and discussion

Investigations of phytoplankton in the radial decanters identified 19 taxons, mostly belonging to the phyla Bacillariophyta. The highest number of taxonia was recorded for the phylum Bacillariophyta where the following species were identified: Diatoma, Navicula and Synedra - dominant species followed by Cymbella, Gyrosigma, Fragillaria, Asterionella, Tabellaria, Meridion and Cymatopleura. In the composition of the Chlorophyta phylum the dominant species was Oedogonium, followed by Ulothrix, Cosmarium and Scenedesmus.

The Cyanophyta phylum was highlighted by the presence of Oscillatoria species and less present Pseudanabaena and Merismopedia species. The Chrysophyta phylum was represented by Ceratium, which showed a maximum growth in June and Dinobryon with a maximum growth in July.

Comparing the two decanters, a reduction in the number of cells can be observed in the case of the radial decanter in which the ultrasound machine is mounted – figure 4.

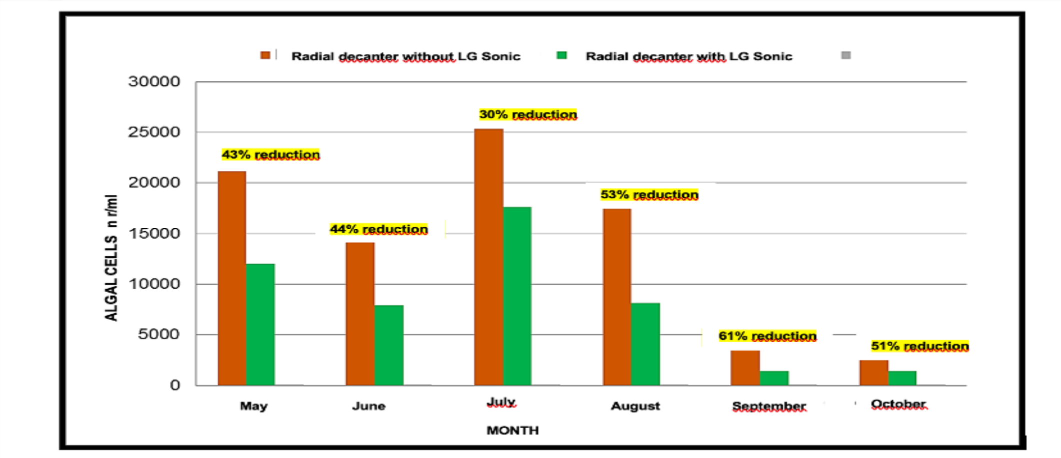


Figure 4- Comparative variation of algal cell concentration in radial decanters with and without ultrasonic algae control devices

Compared to the decanter without the ultrasonic device, in the decanter with this equipment, the algal population was reduced by 30-60%, depending on the calendar period. Thus, in July, when the algal growth was the most significant, being favoured by the climatic conditions, the reduction was the lowest of ~30%. This is also closely related to the nature of the algae, the ultrasonic device being more effective on small algae, filamentous green algae being more difficult to penetrate.

In the decanter where the device is not mounted, algal species have formed many more colonies - Figures 5a, 6a, while in the decanter where the ultrasonic device is mounted the colonies are smaller and fewer, with solitary cells present - Figures 5a, 6a.

Figure 5. a

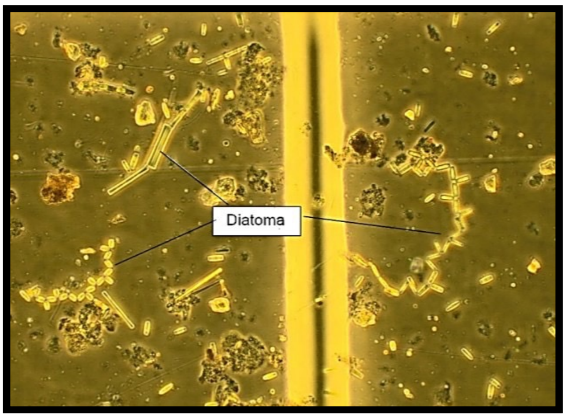


Figure 5. b

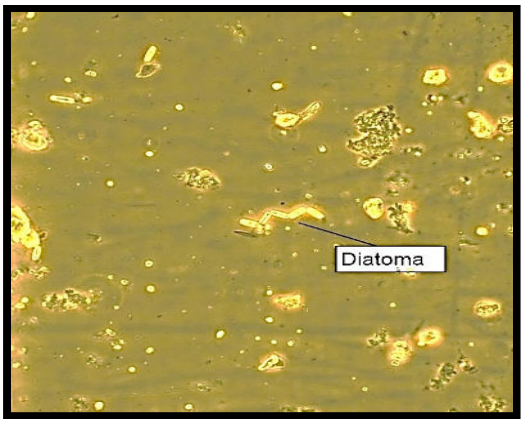
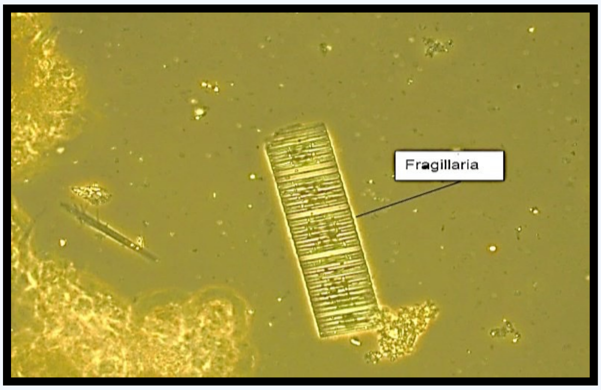


Figure 5. a – colonies of the species Diatoma decantor without LG Sonic;
b – colonies of the species Diatoma decantor with LG Sonic

Figure 6. a

Figure 6. b



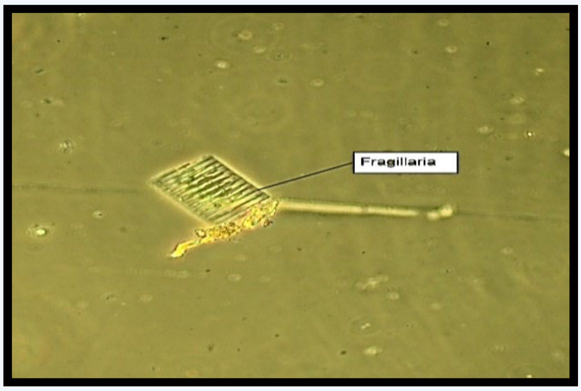


Figure 6- a – colonies of the species Fragillaria decantor without LG Sonic;
b – colonies of the species Fragillaria decantor with LG Sonic.

In the decanter without ultrasonic device it can be observed - figure 7- an algal bloom (Dinobryon species) detected in July, compared to the detection of only algal fragments - figure 8- in the decanter equipped with LG Sonic.

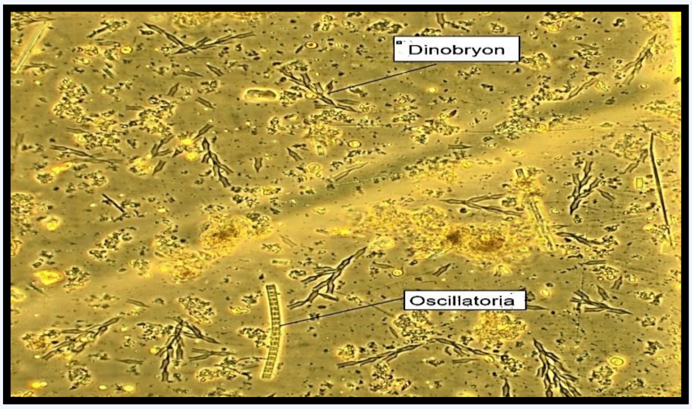


Figure 7- Dinobryon bloom in decanter without LG Sonic

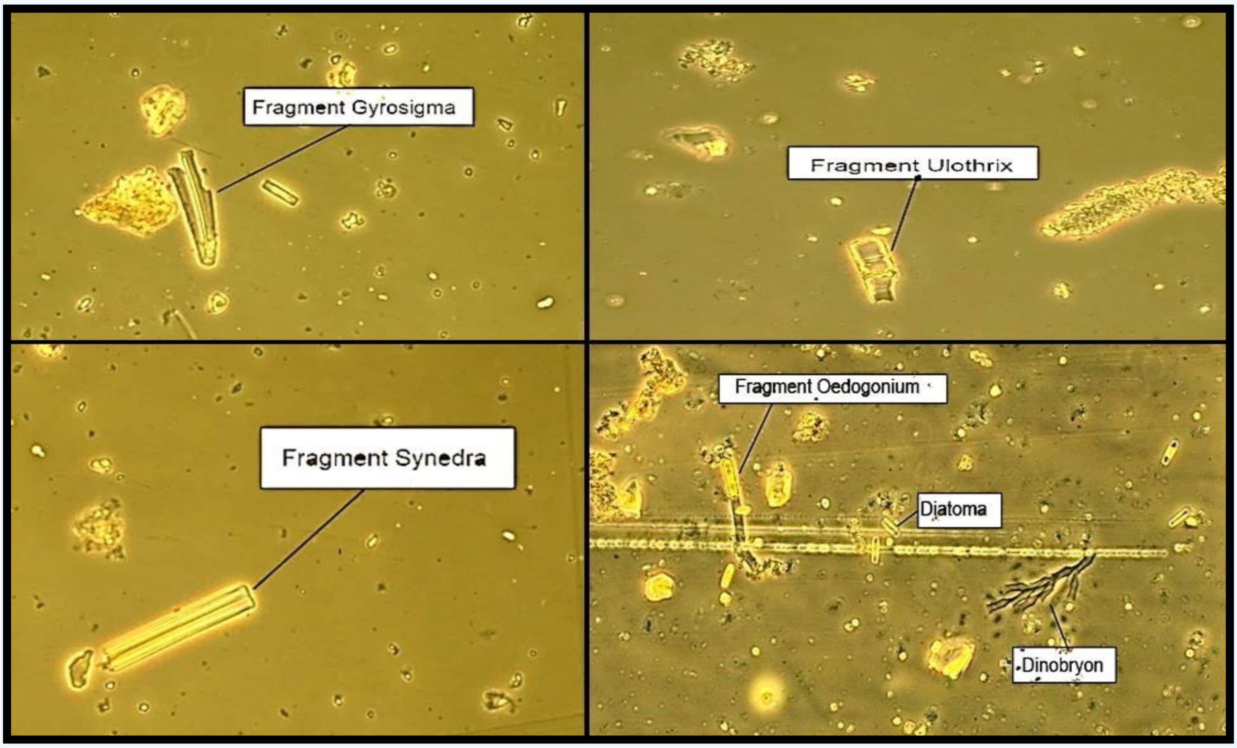


Figure 8- Algal fragments in the decanter equipped with LG Sonic

The process of reducing the algal population using ultrasound technology is influenced by the following factors: the degree of coverage of the decanter by the ultrasound transmitter, the exposure time of the water to the ultrasound, the algal concentration involved, the deposits (sediments) in the decanter that support the growth and development of algae. As a result of the findings, during 2016-2021 the radial decanters were equipped with ultrasonic devices, 4 transmissions per decanter, so that the entire surface of the decanter is covered-figure 9a. In order to optimise the process of reducing the algal concentration in the raw water intake, devices of this type were also installed in the water intakes - Figure 9b.

Figure 9. a

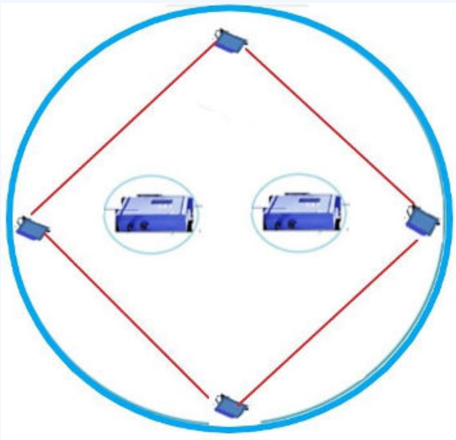


Figure 9. b

Figure-9- a- mounting 4 LG Sonic transmitter on radial decanter
b- mounting transmitter LG Sonic in the water outlet lake

After mounting the 4 transmitters on each radial decanter, the algal concentration reduction efficiency increased, ranging from 50 to 90%, depending on the species involved. Figures 10 and 11 show a comparison of the algal concentration in the water, where 24950 algal cells/ml were detected (Figure 10) and at the outlet of the radial decanters equipped with 4 LG Sonic transmitters -Figure 11 where the detected specimens are 2520 algal cells/ml, representing a reduction of ~89%.

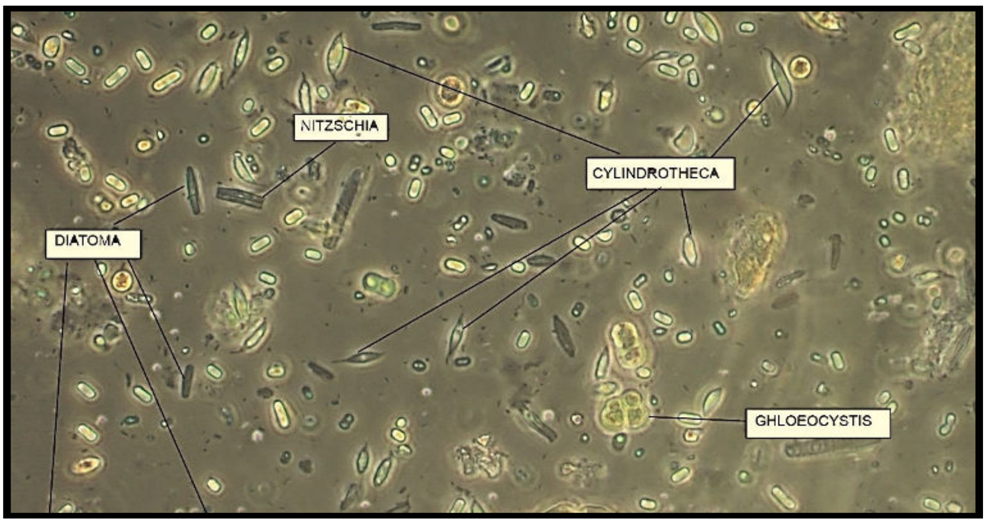


Figure 10- algal cells - raw water

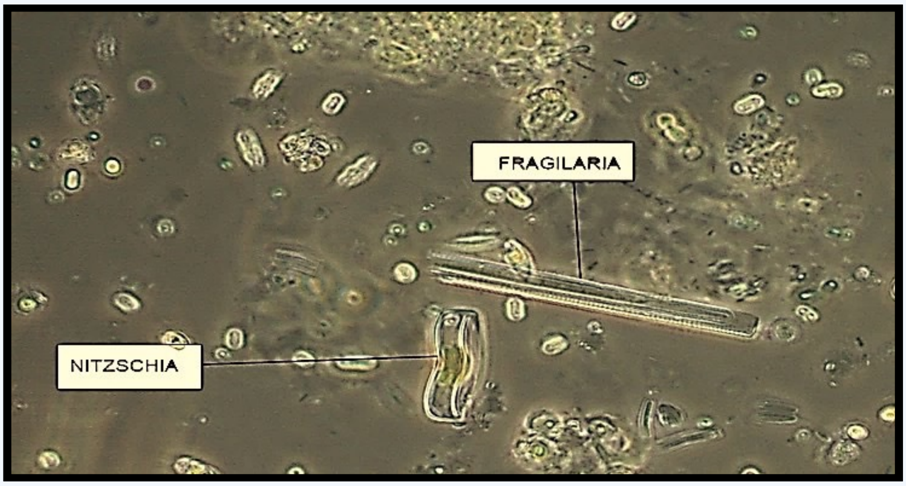


Figure 11- algal cells - after the settling phase

The effectiveness of the ultrasonic algae devices is highlighted in Figure 12, which shows pictures of the collecting trough of the radial decanters when they are switched off and emptied to start the washing and disinfection procedure - before and after the installation of the LG Sonic.

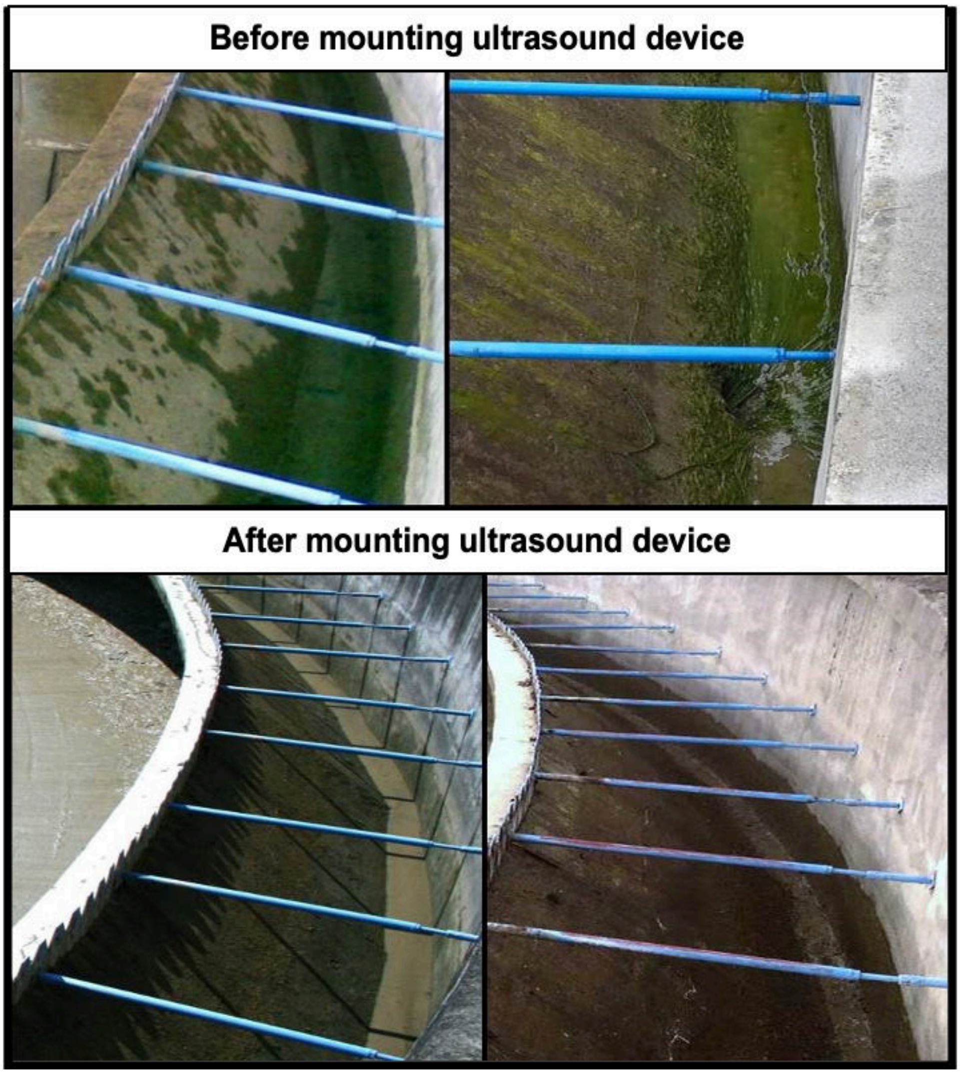


Figure 12- Gutter collector radial decanters when they are stopped for washing and disinfection

4. Conclusions

LG Sonic ultrasonic devices are effective in reducing the algal load depending on the algal species involved and the degree of coverage of the respective installation by the ultrasonic flow. Thus, their efficiency is high (80~90%) in reducing diatom algae, small blue-green algae and lower for filamentous green algae.

The coagulant and flocculant used play a significant role in reducing the algal population in the settling tanks, their ability to trap the algal cells bombarded by ultrasound inside the flocs and their deposition. As can be seen, the process of reducing the algal population in decanters is a complex one, with ultrasound technology being directly involved with the coagulation-flocculation process.

Algae control in treatment plants using surface water subject to drinking water treatment is an essential component of complying with legal requirements for water quality and optimising operating costs.

The implementation of ultrasound technology combined with a rigorous program of washing and disinfection of all treatment facilities (decanters, filters, tanks, basins) and the use of high-performance coagulation-flocculation reagents allows the control of algal cells in the technological process, in a context where climate change has a major impact of accelerating the degree of eutrophication for surface sources subject to drinking water treatment.

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