NATURAL POOL INFO 2023

Natural Pool Wennigsen - Polyplan GmbH

NEWS+FACTS ON NATURAL POOLS

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Editorial

Natural Pool Info Editorial

Dear Readers

The memories of the pandemic's restrictions on pool operations were just fading when the next bad news hit pool operators last year. Due to the gas shortage, pool water temperatures in indoor pools were reduced in order to contribute to energy savings. The situation has since stabilized again, but after covid demonstrated how reliant on the natural world we are for a healthy existence, the gas crisis demonstrated our need on natural resources. Although there may be different supply chains, gas resources are limited.

We have confronted both crises directly „on our own doorstep" in the pools. And both crises have made it clear that humankind must always find ways to live with the conditions that nature sets. In the short term, man can modify them in his own favor, but in the long term, adaptation is always inevitable.

For more than 20 years, the natural pool sector has followed a path of adaptation to natural circumstances and processes. In the last issue, we presented concepts for energy and CO2 neutrality in construction. In this issue, we present the results of an ideas workshop on the future of natural outdoor pools. In addition, some articles are dedicated to a deeper understanding of the biological processes in natural outdoor pools. The better our understanding of these processes, the better we can optimize the planning and operation of natural swimming pools and thus adapt a little further to natural processes. This is our industry's contribution to sustainable living in harmony with natural conditions.

We wish you a lot of fun in the pools this year, be it as an employee or as a guest! If you notice something that needs an improvement, we would be happy to hear from you.

Greetings,
Nina Röttgers, Hannes Kurzreuther, Janne Baden, Leon Müller, Stefan Bruns [Polyplan-Kreikenbaum]
Inga Eydeler, Dr. Antje Kakuschke, Dr. Stefanie Hirch, Dr. Jürgen Spieker [KLS Gewässerschutz]

On behalf of the Working Group Swimming Lakes and Ponds: 'Arbeitsgemeinschaft Badeseen und Schwimmteiche' (ABS)

Natural Pool Biology

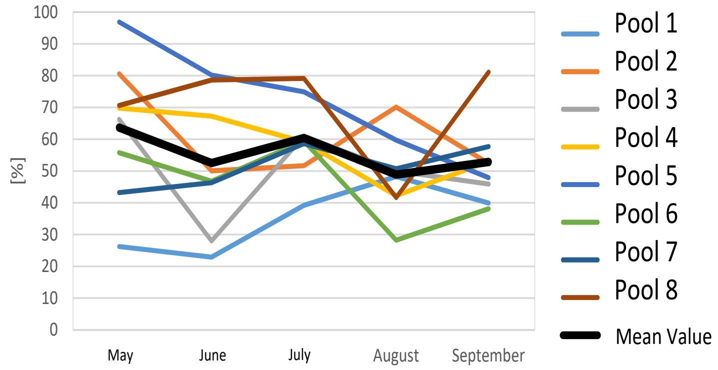
Silicon and diatoms in natural pools

Latest research findings

Diatoms are an integral part of the algal communities that grow in natural outdoor pools. They occur in the open water and in the biofilms of the pool walls. To grow, diatoms require silicon.

In the past, it was often assumed that diatoms were particularly attached to pool walls because of the hard cell envelopes they form from silicon. This was used as an explanatory model for the biofilms that require stubborn cleaning. In the summer of 2022, biofilm investigations were now carried out for the first time in a natural outdoor pool in Switzerland (see„Investigation of film growth in a natural outdoor pool with biotechnological water treatment during ongoing operation"). Here the study revealed that despite high silicon levels, which are elementary for diatoms, hardly any diatoms were present in the biofilm. Instead of diatoms, lime deposits seem to be responsible for the high cleaning effort, which is caused by biogenic decalcification of different algae species. Biogenic decalcification is caused by the photosynthetic activity of the algae. These consume CO2, which shifts the balance of calcium hydrogen carbonate and carbonic acid in the water. As a result, calcium carbonate is then precipitated.

Parallel to the biofilm investigations, the phytoplankton analyses of 8 pools from the years 2010 - 2021 were evaluated. This showed that on average 56% of all algae present in the open water were diatoms. A comparison with the available silicon values of the pools showed that nowhere the natural bath-specific growth limitation limit of 0.065mg/l silicon has been decreased. A limitation would be possible by using iron granules or liquid iron, since silicon binds to iron. However, since diatoms in the biofilm of the pool walls are of no special importance for purification and since diatoms in the open water are no more disturbing than other algae, this is not necessary for regular operation. Exceptions may concern diatoms that should be selectively removed due to their specific characteristics. For example, one application would have been diatoms that grew in a gravel filter in a bath in 2019 and 2020 and thus polluted the pure water. Here, however, the addition of bacteria and a replanting of the filter had also shown success at that time. Thus, silicon limitation by iron is now another tool to address future problems with diatoms. [PK]



Current news on Natural Pools

Natural pool with a view of Mont Blanc

Pool introduction: The Biotope of Combloux

In 2002, the first outdoor pool in France with fully biological water purification was opened in the municipality of Combloux. After 20 successful years of operation, a complete redesign and enlargement took place in 2022, so that the pool with a view of Mont Blanc is now available to visitors again. The bath is not only special in terms of its location, but also has some special features in its operational management.

The first French municipality to accept a public outdoor pool with biological water treatment was Combloux. Based on references from Germany, Austria and Switzerland, the landscape architects from Greenconcept were able to take on the design of the pool at the time - for the operation of which a special permit was required from the authorities. The planning was based on the Bioteich® system, which was represented in Switzerland at the time. According to this method, the water was purified by a shallow water area of 1160 sqm planted with helophytes and hydrophytes on the periphery of the bathing area. Furthermore, the water was purified by a wet filter of approx. 500 sqm before it was fed back into the pool via a waterfall from a height of several metres over various cascades. The bath with a 540 sqm entry area (water depth 0.00-1.80 m) and a 1.80 m deep and 835 sqm swimmer's pool, was at that time approved by the health authorities for 700 bathers per day.

After almost 20 years of operation, the municipality wanted to redesign and enlarge the pool. In addition, the legal regulations for public baths with biological water treatment, which were modified in France in 2019, were to be fulfilled. At the end of 2019, the engineering firm SINBIO, (www.sinbio;fr) in cooperation with Polyplan-Kreikenbaum Gruppe GmbH and the landscape architects Willem Den Hengst et associés, was commissioned with the renovation of the pool.

The refurbishment expanded both outdoor and bathing areas, so that the bath is now licensed for 900 bathers. In addition to the size of the bath, the water treatment system was also adapted to meet current needs. This now contains:

- $441 m^2$ hydrobotanical system planted with emersed hydrophytes with a volume of 485 cbm (pool depth 1 m - 1.40 m). The depth and volume of the hydrobotanics can increase during operation, as this basin is also used as a surge tank.
- 435 sqm sprinklered Neptune substrate filter
- 437 sqm planted submerged Wet substrate filter
- Two drum filters, each designed for a volume flow of 120 cbm per hour.

This means that a total of up to 525 cbm of pure water can be provided per hour.

The construction time for the project lasted ten months and the opening could take place on the 18th of July 2022.

Special features

Filling water: The tap water available for filling is extremely soft or aggressive. With a total hardness < 5°dH and a carbonate hardness of < 2.5, in some cases even < 1 °dH, it is unsuitable for use according to FLL. To buffer this water, only filter material containing lime was used. As a result, the hardness and acid capacity of the water improved, but initially lime precipitation caused the water to become very cloudy and thus delayed the opening.

Purification capacity: These very high purification capacities of $525 m^3$ of pure water per hour (approx. 1/6 of the water volume) do not result from technical reasons, but from the local legal requirements, which in France demand a strongly increased circulation in comparison to the FLL. To realise this, drum filters are successfully used.

The first season

The pool's renovation was warmly received by swimmers in 2022. Also due to the warm summer weather, 900 bathers were counted almost every day until mid-August. A total of 25,000 bathers were recorded between 18 July and 11 September, resulting in revenues of € 145,000.

The twice-weekly sampling to analyse the hygiene parameters showed a water quality in conformity with the French limits for E. coli, enterococci and Pseudomonas aeruginosa. Taking into account the stricter German limits, two values for enterococci and one for Pseudomonas aeruginosa would have been considered as slightly exceeded.

However, the analysis of pathogenic staphylococci, which are not analysed in Germany, caused problems. The limit value for this in France is 20 CFU/100ml and was regularly exceeded when the number of visitors was high. On hot days with a high number of visitors, the values seemed to increase during the course of the day, while the number of visitors on the previous day had no influence on the analysis values. The staphylococci seem to be well degraded by the filter biology between opening hours. This was also evident in the analyses of the clean water, where no limit values were exceeded. However, when the number of visitors is high, the circulation and cleaning capacity does not seem to be sufficient to sufficiently reduce the amount of bacteria in the pool water.

According to various scientific reports, up to 50% of the population are healthy carriers of pathogenic staphylococci, which are not only found in the mucous membranes of the mouth and throat, but also on the skin and especially under the armpits. If bathers do not shower thoroughly before bathing (and preferably wash with soap), these staphylococci are carried into the bath water. This hypothesis was strengthened by the analysis of the shower water collected in the foot basin, which showed extremely high concentrations of pathogenic staphylococci. It can therefore be assumed that the increased input into Combloux can be reduced by improving the showering behaviour of bathers. This will be one of the major tasks for a successful 2023 season, which starts in June. [D. Esser, N. Röttgers]

Source: https://www.combloux.com


Natural Pool Combloux with a view of Mont-Blanc - Photo: D. Esser


Natural Pool Combloux - Photo: D. Esser

Conferences

Future Lab – A glimpse into the future of Natural Pools

Future Lab - ABS Conference - September 2022

At the end of the ABS conference in Tessin on the 27th of September 2022, current topics relating to natural outdoor swimming pools were addressed in a future lab Although the future lab took place at the end of the event, the discussion of the set topics released a pleasantly creative energy among the participants.

The moderator of the future lab: Dr. Jürgen Spieker from KLS Gewässerschutz had given 6 topics which were filled with content by the participants. After a short technical introduction to each topic, the contributions to the discussion were collected on one side of the presentation. The results of each topic are presented below.

For each topic, the participants' contributions and the subsequent discussion elaborated on the specific implications and challenges. The results can be roughly divided into three categories:

- Impacts and challenges on and for visitors
- Impacts and challenges on and for the infrastructure of the natural outdoor pool.
- Water impacts and water quality challenges.

The topics are highly overlapping. for instance, between the topics of energy, technical innovation, and climate change.

Climate change

Climate change will not only affect our environment, but also our behavior and thus our leisure activities. The utilization of natural outdoor pools will be impacted by the trend toward higher temperatures. While the total amount of precipitation is not expected to change, a different distribution towards longer dry seasons and individual heavy rain events is to be expected. In principle, it is expected that the higher temperatures will lead to an increase in visitor numbers. This may be accompanied by a change in the composition and expectations of visitors. A change in the composition of visitors could result from the fact that parts of the population who have not been to a public bath before (or have not been for a long time) discover the „habitat natural outdoor pool" for themselves. This is associated with the fact that the distribution of the areas will probably change towards an increased number of shaded areas and shading in general. The colour of the foil or the pool walls and bottom can also be used to control the heating of the water. It is possible that light colours are advantageous, but they pose a great challenge in terms of maintenance. The extent to which changes in growth and biofilms can be controlled via the colour of surfaces under water has not yet been researched (see also article in this Naturbad Info:„Curse and blessing of biofilms - a very special habitat"). During heavy rain events, a very large amount of water accumulates within a short time. In most cases, attempts are made to drain off the water. It would be better to retain and effectively infiltrate or store the water, possibly as fill water or water for sprinkling and irrigating surrounding green spaces. This can be very important, especially in times of drought.

The currently valid regulations (FLL 2011) provide for an upper temperature limit of 25°C, which may be exceeded for a limited period (5 days) (not higher than 28°C). From a water ecology point of view, the water temperature must not exceed 30°C, because then the performance of the ´´Biozönosen´´ (biotic communities), which are responsible for water purification, strongly decreases. This can also change the water quality (for the worse) and new algae and animal species may appear whose role in the overall system is not foreseeable.

Energy

Climate change and energy production and consumption are closely related, as it has been proven that climate change is also caused or accelerated by the burning of fossil fuels. Currently, high prices for energy are an additional burden for operators of natural outdoor pools. Saving energy and the efficient use of the required energy are therefore major challenges.

Energy should be used as sparingly as possible. Of course, it would be best if every single visitor practiced this. By providing information on how to use energy sparingly, visitors to a natural outdoor pool can possibly also be encouraged to use energy (and water) sparingly at home.

In the natural outdoor pool itself, all possibilities should be utilized to make use of solar energy. For this purpose, photovoltaics should be expanded and the showers should also be included in the concept. This should also play a major role in the new version of the regulations for natural outdoor pools. The water itself could also be used as an energy source by using the excess heat for energy at night or during the day when temperatures are too high.

Technical innovation

Has the development of natural outdoor pools already reached its end? The existing public natural outdoor pools show a high operational safety. The water ecological quality management carried out in many pools (see Naturbad Info 01/2021) and the use of the software DANA 2.0 (see Naturbad Info 2022) have made a great contribution to this and many technical specifications are described in the existing regulations (FLL). Basically, the following applies: the aquatic biological purification processes via biofilms (in filter bodies) and free (good) bacteria, phytoplankton (suspended algae) as well as zooplankton (suspended animal organisms in the water) in the water are the essential characteristic of a natural outdoor pool. Technical processes control and regulate aquatic biology to varying degrees by feeding the treatment systems. Future technical innovations will therefore have to deal with the requirements imposed by climate change and energy availability.

Technical innovations were discussed mainly in the areas of energy conservation and water use. Thus, the expansion of solar energy and the sensible use of water were advocated. In principle, the pumps in the filter and treatment systems should also be


KLS Gewässerschutz GmbH

Ideenwerkstatt

ABS Tagung 26. – 27.09.2022 Ein Blick in die Zukunft der Naturbäder Folie 1

Future Lab - ABS Conference 2022 - opening page (german original) - image: KLS


KLS Gewässerschutz GmbH

Mikroplastik

Kunst im Bad

Energie

Technische Innovation

Nährstoffrückhaltung

Klimawandel

ABS Tagung 26. – 27.09.2022 Ein Blick in die Zukunft der Naturbäder Folie 2

Future Lab 2022 - Topics - overview page (german original) - image: KLS

operated as energy-efficiently as possible. The area of alternative building materials was not discussed in detail. However, there is certainly still great potential in this area.
Can bathers contribute to energy generation during their stay? Here, too, there are no limits to the imagination.

Nutrient retention

The amount of nutrients in the water of a natural outdoor pool is crucial for the water quality. Since a high visual depth and a low biomass of phytoplankton (floating algae) and other algae such as filamentous algae and algal coverings are aimed for (see FLL), a concentration of phosphorus of less than 0.01 mg/L is required. Phosphorus as a production-limiting nutrient is of greater importance than nitrogen (in the form of nitrate and ammonium). Phosphorus, once it enters the system, can only be removed from the water by purification operations (biomass removal). Before that, however, much of the phosphorus in the system is immobilized by the activity of algae and zooplankton and in the treatment systems.
The Redfield ratio indicates the ratio of the nutrients phosphorus (P), nitrogen (N) and carbon (C) in marine phytoplankton (floating algae). It is assumed that at this ratio there is an optimal distribution of nutrients in freshwater as well. Whether this is really the case has not yet been scientifically studied for natural freshwater pools. With the future challenges of climate change and its potential impact on water quality, this would be an interesting topic of future research.
In principle, the input of nutrients from the environment should be limited so that no problems can arise in the bath itself. The steering of visitors towards the water must already be solved in terms of planning. Inputs from visitors (sweat, skin care products) must also be taken into account and minimized.

Art in pools

Natural outdoor swimming pools are frequented by a large number of visitors. Most visitors spend a long time in the bath, which is spent bathing, playing and relaxing. Art (and culture) in the bath could be another utilization option that can mobilize groups of visitors who previously had little access to the natural outdoor pool.
In France, for example, concerts are held in natural outdoor pools. This shows that a more extensive cultural use of a pool is possible in principle. In addition to promoting the pools as an additional art platform, attractions specific to natural pools were also mentioned. For example, the creation of a „limnological window in the hydrobotany“, i.e. a viewing window through which visitors can explore the underwater world of a natural open-air bath, as in an aquarium. In order to be able to show visitors the organisms that are important for water purification, a special (walking) exhibition with meaningful photos and descriptions of the organisms of the phyto- and zooplankton would also be feasible.

Microplastics

Are there risks from micro plastics in natural outdoor pools? This question cannot yet be answered. In principle, however, the increasing spread of micro plastics in the environment is seen as problematic. There are still uncertainties in the analytics and before already in the sampling.
In addition to visitors who introduce microplastics into the water of natural outdoor pools via their swimwear and possibly also via skin protection products, microplastics can also enter the water via construction materials such as footbridges. Whether and how microplastics behave in the natural outdoor pool system should be clarified.

Conclusion

In a very engaged event during the ABS conference in Tessin, ideas for the further development of natural outdoor pools were collected in 6 thematic areas. The participants discussed the topics of climate change, energy, technical innovations, nutrient retention, art in the bath and the influence of micro plastics with regard to the effects and challenges in the future operation of natural outdoor pools.
The future will show whether and how many of the ideas can be put into practice. However, each operator and the responsible staff in the pools can start to implement some of the ideas for themselves and locally in their own pools. Many of these ideas will also be incorporated into the future development of the regulations and thus possibly put into practice.
Summaries of each topic are shown on the right.
[KLS]

Climate change

Impacts and challenges		
Visitors	**Infrastructures**	**Water**
higher visitor numbers	Distribution of the areas	Change in water quality
Change in the composition of the visitors	Foil colour	Water scarcity, water availability
Changing the expectations of visitors	Shaded areas, shading	Water source
	Create storage capacities (keyword: Sponge City)	Coupling swimming ponds with rainwater treatment in cities
		Increased growth of algae
		Increased occurrence of parasites, black flies, etc.

Energy

Impacts and challenges		
Visitors	**Infrastructures**	**Water**
Energy efficiency and presaving	Expand photovoltaics on all possible places	Use of heat pumps (also for cooling water)
	Energy-saving concepts	
	Adaptation of the rules and regulations	
	Solar energy for e.g. showers	

Technical Innovation

Impacts and challenges		
Visitors	**Infrastructures**	**Water**
Alternative energy generation by bathers	Expansion of solar systems	Water reuse
	Combination of heating and cooling	Energy saving rapid filter
	Alternative building materials	
	Indoor swimming pools	

Nutrient retention

Impacts and challenges		
Visitors	**Infrastructures**	**Water**
Entry pathway visitors (sweat, skin care products)	Observe input paths from open areas	Check Redfield ratio for natural pools

Art in Pools

Impacts and challenges		
Visitors	**Infrastructures**	**Water**
Educational mission	Pools also as an art platform	Exhibition of e.g. plankton organisms and other aquatic organisms
Concept art and customer communication, public relations	Limnological Window in Hydrobotany.	
Inclusion of art in pools in database	Promotion of art on the building	
In France: theater and concerts in the pool		

Microplastics

Impacts and challenges		
Visitors	**Infrastructures**	**Water**
Entry pathways	Increasingly plastic materials in construction (walkways)	Survey of studies in natural outdoor swimming pools
		Possibility of monitoring via zooplankton
		Impact of microplastics on biofilms (filter systems).

Biology

Pseudomonas aeruginosa in pool water

Quantitative determination of Pseudomonas aeruginosa in pool water

Introduction

Pseudomona aeruginosa is a ubiquitously distributed bacterium that is also found in nutrient-poor waters such as drinking water and swimming pools. *Ps. aeruginosa* has low nutrient requirements and is able to utilize a wide variety of substrates [1, 2]. In addition to aliphatic hydrocarbons such as kerosene, it also degrades xenobiotics such as pesticides and other toxic substances. Since Ps. aeruginosa can be pathogenic especially for immunosuppressed people, it has been selected as an indicator germ for water quality in swimming pools with a maximum value of 10 germs per 100 ml [3].

The previous detection method according to DIN EN 16266 has the disadvantage that the accompanying flora present in bathing water massively interferes with the test, makes the evaluation more difficult and therefore often too high germ counts are measured [4]. The recommendation of the Federal Environment Agency (UBA) in 2008 to perform the test at 42°C led to better results, but did not solve the problem of the disturbing accompanying flora [5].
A method increasingly used in recent years for the detection of specific microorganism species is based on the principle of gene probe technology [6]. The basis of this technology is the knowledge gained in recent years that many bacterial species have a characteristic specific gene sequence. Genes consist of DNA, which contains the information for the formation of all proteins of a living being. This information is formed by the gene sequence, which in turn is formed by

the sequence of four different „letters“ of different lengths, the nucleotide bases. For example, the genome of *Ps. aeruginosa* contains 6.3 million of these nucleotide bases, which carry the information for 5,570 genes [7]. Poly- or oligonucleotides can now be synthesized for the species-specific parts of the gene sequence (so-called complementary sequences), which attach exclusively to exactly these sites of the genome. These gene probes can then be further coupled with dyes to make them visible and quantitatively measurable.

In 2003, a gene probe test for *Ps. aeruginosa* was presented, but it has not yet been used in bathing waters [8]. A comparison of the procedure of the gene probe test and the method according to DIN EN 16266 showed that the gene probe test has advantages over the conventional method in terms of handling and time requirement: for example, the gene probe test requires six procedural steps with a total time requirement of only 26 hours, while the conventional method involves seven steps that take between 112 and 208 h [9].

ASA was therefore commissioned by the ABS to apply the gene probe test in the field of natural swimming pools and to compare it with the currently used detection method on cetrimide agar according to DIN EN 16266.

Investigations in the laboratory

Extensive laboratory tests were already carried out in 2013 using standardized bacterial suspensions. For this purpose, pure cultures of the strain *Ps. aeruginosa* PAO 1 (DSMZ 22644) with different bacterial counts were prepared and these were inoculated with 1,000 K/ml *Ps. putida* and the bacterial mixed culture ASA T, respectively. The bacterial suspensions prepared in this way were analyzed for *Ps. aeruginosa* content using DIN EN 16266 (with incubation at 30° and 42°C) and the gene probe test.

In summary, the following findings were obtained, which were also published [9]:

- The bacterial counts for *Ps. aeruginosa* determined with the DIN method were almost always higher in the presence of other bacteria compared to the gene probe method, in some cases more than twice as high.
- Irrespective of the detection method, the analysis of water samples showed that the sample pretreatment in the laboratory has a significant influence on the results. influence on the results. The reason for this is probably the property of *Ps. aeruginosa* cells to aggregate or grow in biofilms [10]. Thus the variations in measured values within a sample could be reduced by a simple sample pretreatment (stirring for 30 min) could be significantly reduced (up to < 5 %).
- Since *Ps. aeruginosa* grows in biofilms under low nutrient conditions, a homogeneous distribution in bathing ponds seems rather doubtful. Thus, samples taken from bathing waters are only limited or rarely representative with regard to this germ.
- Aspects such as the location and time of sampling, e.g. shortly after an accidental break-off of biofilm parts, can significantly influence the measured bacterial count and thus call into question the significance of the measured values with respect to swimming pool hygiene into question or at least put it into perspective.

Comparison of detection methods through extensive field trials

In order to put the findings obtained in the laboratory setting and the test comparison on a broader data basis, the following eight natural pools were selected for field tests during the 2015 bathing season:

- OSIR Skalka, Swietochowice, Polen
- Sigtuna kommun, Märsta, Schweden
- Natural Pool Herrenberg
- Stadionbad Bremen
- AQWA Walldorf
- Natural Pool im Staden, Idar-Oberstein
- Natural Pool Riehen, Schweiz
- Natural Pool Froschloch, Dortmund.

Sampling was carried out by the respective investigation offices or laboratories or operators.

Samples were shipped in cool boxes with refrigeration elements and 24 h service.

Samples were stored on ice until processing. Due to possible inhomogenities, sample pre-treatment in the form of mixing for at least 30 min (magnetic stirrer) was performed.

The determination of *Ps. aeruginosa* was carried out by the gene probe test [8] and according to DIN EN 16266 (with UBA recommendation 2008).

Results

The original assumption that the gene probe method would detect lower bacterial counts could not be confirmed by the data from all eight pools. The reason for this is certainly that the ratio between foreign germs and *Ps. aeruginosa* was significantly higher in the laboratory tests than in most samples from the field tests. This is exemplified by the values from natural bath a (Figure 1, Table 1).

Thus, the DIN EN 16266 method appears to be more susceptible to interference in the presence of strong accompanying flora. The reason for this could be that the *Ps. aeruginosa* cells are overgrown by the accompanying flora and are thus not detected.

Furthermore, the results showed that it is important to measure the samples as soon as possible: The results of the samples from natural pool B show that when stored for more than 24 hours, the bacterial count decreases despite refrigeration (Table 2)

An opposite effect of the storage times was observed with samples from natural pool C. The number of bacteria increased in some cases by more than ten times after several days of storage (Table 3): Here, the bacterial count values increased by more than ten times in some cases after several days of storage (Table 3). The reason for this is probably the property of *Ps. aeruginosa* cells to aggregate or grow in biofilms, which become detached during storage. This is probably also the reason why duplicate values could not be evaluated in some cases during the first analysis (after receipt of the sample).

Irrespective of the interpretation of the results, biofilm formation by *Ps. aeruginosa* again proves to be a problem for obtaining representative and homogeneous samples. This again raises the question of whether it makes sense to select this bacterial species as a lead bacterium for assessing the hygiene of swimming waters.

Summary

The gene probe test compared to the DIN EN 16266 method is less influenced by the accompanying bacterial flora. In water samples with low bacterial counts, both test methods provide similar results. Even under controlled cool transport and storage conditions, it is essential to measure the water samples as quickly as possible.

The ability of *Ps. aeruginosa* cells to aggregate or grow in biofilms makes it difficult to collect representative and homogeneous samples from bathing waters. The suitability of *Ps. aeruginosa* as a guide germ for assessing swimming pool hygiene thus seems questionable. [ASA]

Dr. Arno Cordes, Petra Hoferichter, ASA Spezialenzyme

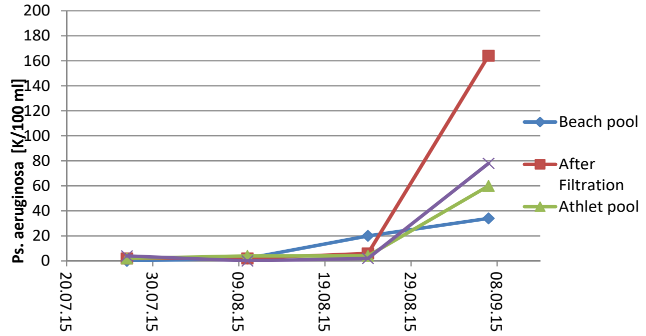


Figure 1: Measured values Ps. aeruginosa (gene probe) Natural pool a (06-09/2015)

Literature: 1. Wingender, Hambsch, Schneider.: Mikrobiologisch-hygienische Aspekte des Vorkommens von Ps. aeruginosa im Trinkwasser. (2009)
2. Schoenen: Wachstumsbedingungen von Ps. aeruginosa (...) in Trinkwasserversorgungssystemen - Gfw-Wasser Abwasser (2009) 1012-1015
3. Hygienische Anforderungen an Kleinbadeteiche - Bundesgesundheitsbl - Gesundheitsforsch - Gesundheitsschutz 46 (2003) 527–529
4. Heinemeyer, Luden: Probleme bei der Anwendung der DIN EN 12 780 zum Nachweis von Ps. aeruginosa(...)–Gesundheitsschutz 52 (2009)
5. Empfehlung der Schwimm- und Badebeckenwasserkommission: Hinweise für die Überwachung von Kleinbadeteichen zur Bestimmung von P. aeruginosa Bundesgesundheitsbl - Gesundheitsforsch - Gesundheitsschutz 52 (2009) 370
6. Schleifer, Ludwig, Amann: Gensonden und ihre Anwendung in der Mikrobiologie. Naturwissenschaften 79 (1992) 213-219
7. Stover, et al: Complete genome sequence of Pseudomonas aeruginosa PAO1 - Nature. 406(6799) (2000) 959-964
8. Snaidr: Gensonden zum schnellen und spezifischen Nachweis von Pseudomonas aeruginosa. GIT Labor-Fachzeitschrift. 3 (2003) 2-3
9. Cordes, Hoferichter: Quantitative Bestimmung von Pseudomonas aeruginosa (...) - AB Archiv des Badewesens 6 (2014) 360-366
10. Hummel, Umweltbundesamt: P. aeruginosa im Badewasser
6. Nordbayerische Trinkwassertage 26. - 27.09.2012

Table 1: Results natural pool a

ASA Sample Nr.			*Ps. aeruginosa* [K/100 ml]	
	Sampling location or designation	Date	DIN EN 16266	Gene probe test
12	Strand 23/6 (Beachpool)	26.06.15	27	17
13	Hopp 23/6 (Jumppool)	26.06.15	46	30
14	Pumphus 23/6 (After filtration)	26.06.15	70	35
15	Motion 23/6 (Athlet pool)	26.06.15	19	11
53	Beachpool 1	27.07.15	0	0
54	After Filtration 2	27.07.15	0	2
55	Athletpool 3	27.07.15	0	2
56	Jumppool 4	27.07.15	2	4
86	Beachpool 1	10.08.15	0	2
87	After Filtration 2	10.08.15	0	2
88	Athletpool 3	10.08.15	8	4
89	Jumppool 4	10.08.15	2	0
116	Beach Pool 1	24.08.15	0	20
117	After Fillration 2	24.08.15	0	6
118	Swimming Pool 3	24.08.15	4	4
119	Jumping Pool 4	24.08.15	0	2
172	After filtration 1	07.09.15	50	164
173	Beach pool 2	07.09.15	10	34
174	Jump pool 3	07.09.15	18	78
175	Athlet pool 4	07.09.15	40	60

Table 2: Results natural pool b

ASA Sample Nr.			*Ps. aeruginosa* [K/100 ml]	
			According to storage time	
	Sampling Location	Date	2 Days	6 Days
23	Clean water 1 (Reinwasser 1)	07.07.15	42	3
24	Clean water 2 (Reinwasser 2)	07.07.15	80	0
25	Pool water 3 (Beckenwasser 3)	07.07.15	64	0
26	Pool water 4 (Beckenwasser 4)	07.07.15	70	0

Table 3: Results natural pool c

ASA Sample Nr.			*Ps. aeruginosa* [K/100 ml]	
			According to storage time	
	Sampling Location	Date	1 Day	6 Days
124	P1	25.08.15	3	80
125	P2	25.08.15	10	1.000
129	P6	25.08.15	0	10
130	P7	25.08.15	26	20
135	P16	25.08.15	0	30
136	P17	25.08.15	30	1.460
137	P22	25.08.15	>400	1.800
138	P23	25.08.15	>400	1.500
145	P3	26.08.15	6	100
149	P7	26.08.15	>400	13.700
150	P8	26.08.15	20	550
153	P11	26.08.15	0	1.285
154	P16	26.08.15	70	670
155	P17	26.08.15	>400	600
156	P20	26.08.15	6	100

Biology

The curse and blessing of biofilms - a very special habitat

Biofilm: formation, organisms and chemical processes

Biofilms are found in all natural and artificial biotopes where aqueous or moist living conditions with a sufficient supply of nutrients allow microorganisms to grow. In the pool areas of natural outdoor pools, they therefore form on walls, stairs or slides, among other places. In the filter areas, where they form around the granules/stones of the filter materials, they play a crucial role in the cleaning processes. The following explanations are intended to give a small insight into the complexity of these extraordinary habitats.

Biofilms do not have a uniform structure at all, but have channels, filaments and water-filled pores, which cause an inhomogeneous distribution of the microorganisms. In addition, the volume of a biofilm changes as a result of the accumulation and washing away of microorganisms, but also as a result of their growth and death. The organisms are actively and passively displaced within the biofilm, which also causes their spatial distribution to vary greatly (Figure 1).

Biofilm formation

The formation of a biofilm begins with an adsorption phase, in which organic substances of an aqueous environment adhere to a surface and form a food base for organisms. Planktic cells of the surrounding medium, such as bacteria, are thus attracted and attach themselves. This process is still reversible in the initial phase. In the subsequent development phase, bacterial cells in particular secrete polymeric substances, whereby they attach irreversibly to prevent washout, and subsequently begin cell division and multiplication. In the growth phase, cell division and polymer production continue to increase, resulting in significant thickness growth of the biofilm. In the following plateau phase, biofilm growth and erosion maintain an equilibrium. The final phase is the dispersion phase, in which the bacteria detach again as the nutrients are depleted or the living conditions have deteriorated.

Organisms in Biofilms

The composition of organisms in a biofilm is highly variable and depends to a large extent on the light and nutrients of the surrounding medium. Accordingly, biofilms under light exclusion, such as those found in filters and sediments, are colonized by heterotrophic organisms, especially bacteria. Autotrophic biofilms on light-exposed and sunlit substrates are dominated by organisms capable of photosynthesis. These biofilms are found in natural pools, especially on stones and foils.

An important group of organisms that live in a biofilm and strongly characterize it are bacteria. As indicated earlier, some bacterial species are capable of forming a mucus layer of extracellular polymeric substances (EPS). This layer consists primarily of polysaccharides, a variety of proteins, lipids, phospholipids, glycoproteins, glycolipids, extracellular DNA, lipopolysaccharides, and up to 97% water. In an outdoor pool, these substances cause the slippery coatings on pool walls and floors, which increase the risk of slipping and accidents. On the other hand, they are the nutritional basis of many organisms, e.g. in the filter, and thus enable the colonization and formation of the complex biofilm.

The composition of the bacterial community in a biofilm is highly variable. On the one hand, very useful bacteria, which among other things condition the desired self-cleaning process in the natural pool, are an important component. Examples of these are *Nitrosomonas* and *Nitrobacter*, which convert ammonium to nitrite and then to nitrate during nitrification, a part of the nitrogen cycle, when organic matter is broken down. A stable biofilm in the filters of a natural bath is therefore a basis for the functioning of the self-cleaning process of the plant.

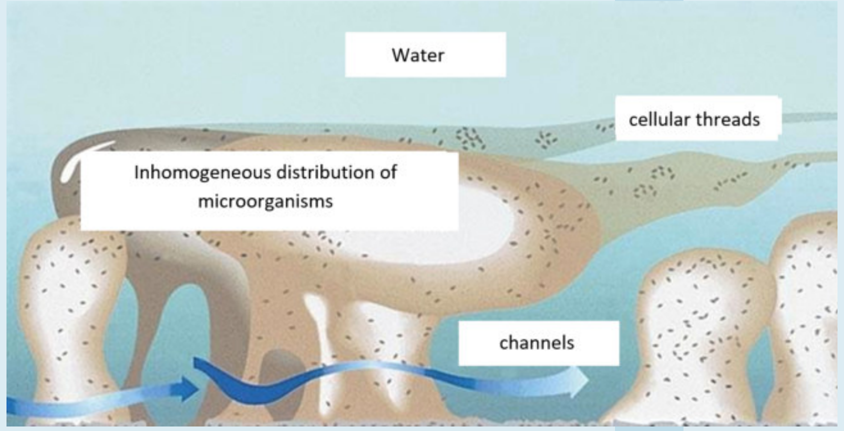


Figure 1: Schematic of a biofilm with pores, channels, and cell filaments (Source: Centre for Biofilm Engineering, Montana State University, figure modified)

On the other hand, germs that are pathogenic for humans can also be found in biofilms. Examples are *Legionella* bacteria, *Pseudomonas* or *Staphylococcus*. In natural swimming pools, the germ *Pseudomonas aeruginosa* is therefore used as a hygiene parameter within the framework of health monitoring, as this germ can cause wound infections and infections in humans, e.g. in the eyes and ears. It is not uncommon for bacterial counts in pool water to rise temporarily when cleaning measures release the bacteria from the biofilm. However, biofilms are not only the habitat for bacteria. Depending on the location and nutrient supply of the biofilm, algae, fungi and various *protozoa* such as *amoebae* or *ciliates* also use this habitat. Biofilms therefore form an essential component in the food web.

Algae are characteristic of autotrophic biofilms, especially those exposed to sunlight. In natural pools, therefore, filamentous green and yoke algae are often found on the films of the pool walls or on stones (Figure 2, see also KLS article „Uninvited bathers“ in Naturbad Info 01/2020).

In addition, diatoms and blue-green algae are also frequently found in and on biofilms. Two KLS-Polyplan pilot studies provided new insights into this.

Pilot Study 1: In a natural swimming pool, there was a reduction in the depth of visibility in early summer. Therefore, the algae composition of the pool and clean water was analysed microscopically. Interestingly, the algal biomass was higher in the clean water than in the pool water, indicating that algal growth had occurred in the filter. In particular, green algae and diatoms were found. A species analysis of the dominant pennate diatom revealed *Nitzschia palea* (Kützing) W. Smith1856 (Figure 3). This species has a benthic lifestyle. That means it lives on substrates, so it is biofilm-associated. More interestingly, this species is capable of heterotrophic metabolism in the absence of light, and therefore can apparently reproduce in filtration systems of pools.

Pilot Study 2: In another joint study, the film growth in a natural outdoor pool was investigated qualitatively and quantitatively for the first time in the course of a bathing season. Details of this study can be found in the corresponding article in this Natural Pool Info.

Figure 2 (2 Photos): Filamentous algae on pool walls and on stones in a natural pool (photos: A. Kakuschke, KLS)

All algae have in common that they produce oxygen, i.e. create an aerobic environment, and consume carbon dioxide. The latter causes an increase in pH. This shift in the lime-carbonic acid balance causes unsightly lime precipitation on the pool walls and thus increases the cleaning effort.

Biochemical processes in Biofilm

In biofilms, a large number of chemical, biological and physical processes take place in a very confined space.

In the surface area at the boundary layer to the aqueous medium, aerobic processes in particular take place, such as:

- the oxidation of iron: Fe2+ to Fe3+
- the oxidation of Ammonium to Nitrat: NH4+ to NO3- (via NO2-)
- the oxidation of manganese: Mn2+ to Mn4+
- the oxidation of carbon compounds to CO2/H2O
- the oxidation of hydrogen sulfide to sulfate: H2S to S and SO42- respectively

In the basic area, where fewer exchange processes take place, anaerobic processes are more likely to occur. Examples of these are:

- the reduction of nitrate to nitrogen: NO3- to N2 (also to NO2- and NH4+)
- the reduction of iron: Fe3+ to Fe2+
- the reduction of manganese: Mn4+ to Mn2+
- the reduction of sulfates: SO32- + SO42- to SO2-

Corresponding biochemical gradients are formed across the thickness of the biofilm, creating a habitat for a wide variety of microorganism requirements. The biofilm not only protects the microorganisms from being washed out, but also from biocides and other toxic substances. The substances are bound in the mucus layer in which the microorganisms are embedded and therefore do not enter the cells. Furthermore, the biofilm provides space for the interaction of various microorganisms and the associated biochemical metabolic processes.

Curse and Blessings

In summary, it can be said: Biofilms fulfil vital tasks in swimming ponds, natural pools and outdoor pools with biological water treatment. These involve the uptake and fixation of nutrients (e.g. phosphates), the uptake and metabolism of organic substances, the conversion of nitrogen compounds or the protection of microorganisms. They are instrumental in water purification and form an important basis in the food web and for species diversity. Their curse lies in slippery coatings or lime precipitates, which cause an unsightly appearance in addition to an increased risk of slipping and accidents. Therefore, biofilms lead to an increased maintenance effort in the pool areas, but their development in the filter area should remain uninterrupted as far as possible. [KLS]

Literature:
Flemming et al. (2016) Biofilms: An emergent form of bacterial life.
Nature Reviews Microbiology. Volume 14, pp 563-575.

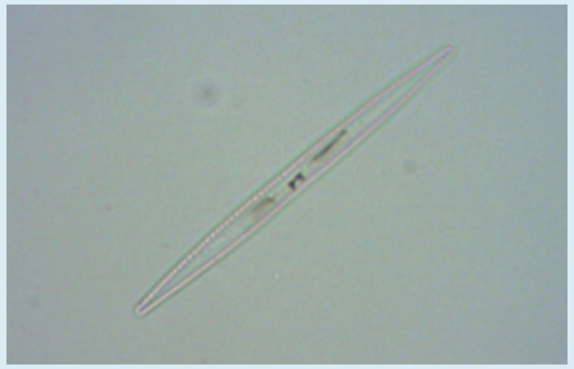


Figure 3: Benthic diatom *Nitzschia palea* from a filter of a natural pool (Photo: A. Kakuschke, KLS)

Biology

Nutrient precipitation in pool operation

Study on phosphorus reduction

Phosphorus reduction is one of the central control mechanisms in the operation of pools with biological water treatment and the phosphorus concentration is one of the design parameters according to the FLL guideline. If the nutrient is present in too high a concentration, the conditions for algae growth improve with the corresponding negative effects on pool operation. The main input pathways here are the bathers themselves (74 mg Pges/bather) and the filling water. While the inputs caused by bathers are degraded by biological water treatment, relevant concentrations are often present in the filling water, which require additional treatment. The use of adsorbers and iron(III) chloride has proven successful in the past. Various manufacturers are currently marketing lanthanum as an alternative for the reduction of phosphorus in water. However, the initial concentrations used are usually higher than those found in pools with biological water treatment. Thus, the manufacturer's data cannot be transferred to the use in pools without further consideration. As part of a study at the Institute of Water Management at the Technical University of Berlin, the use of iron(III) chloride and lanthanum was compared in terms of orthophosphate concentrations using jar tests. For this purpose, among other things, filling water and pool water from the natural open-air swimming pool in Premnitz were used. The tests were carried out in the summer of 2022. A summary of the results is shown below.

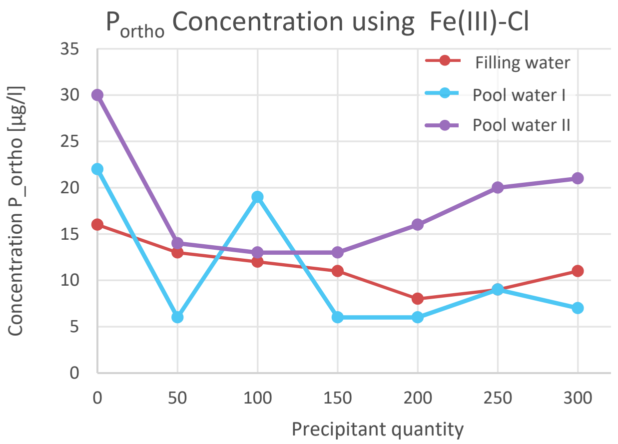


Figure 1: Evaluation of the use of Fe (III)-Cl as precipitant

While the addition of lanthanum did not have any significant effects on the pH value, a clear drop in the pH value can be observed with the addition of iron(III) chloride. Especially from a dosage >200µg per litre, the pH value drops drastically to below 4. This is probably one of the reasons for the renewed increase in the Portho concentration. It is striking that for both precipitants an optimum of nutrient reduction is present at an addition between 50-150 µg/l. With regard to the tests carried out, there is no clear advantage for one of the two precipitants. Both have to be significantly overdosed stoichiometrically to achieve the desired effect - the reduction of phosphorus. Since the drop in the pH value when using Fe(III)-Cl is only selective and temporary, this does not pose a problem in most operational processes. From an economic point of view, lanthanum is the more expensive alternative for the total P concentrations typical in pools. The extent to which it nevertheless represents an alternative precipitant must be considered on a site-specific basis.

D. Ladwig, N. Röttgers, T. Guggenberger

The comprehensive study can be obtained from Tom Guggenberger, Department of Urban Water Management, Technical University Berlin.

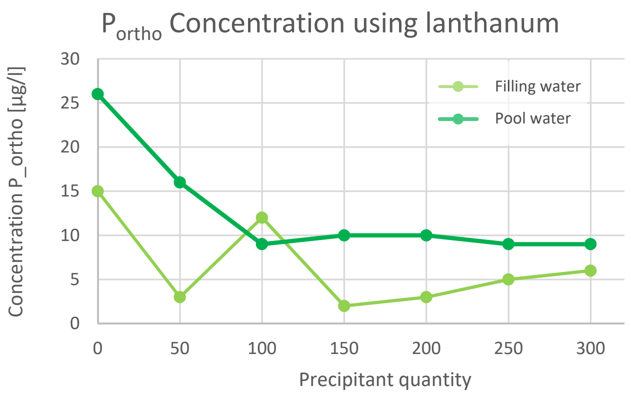


Figure 2: Evaluation of the use of lanthanum as a precipitant

Current news on Natural Pools

Radio-based data transmission in pool operation

Data transmission with LoRaWAN

The secure and permanent availability of water treatment measurement data is crucial for the (automated) operation of natural outdoor pools and spas. For this purpose, the technologies of the so-called „Internet of Things" (IoT) can be used, which are not only applicable for the automation of industrial processes or the use in smart homes, but also for the transmission of measured values in the pool sector.

A transmission technology developed specifically for the IoT is LoRaWAN (Long Range Wide Area Network). In order to operate, it must be composed of three components: a LoRa sensor, a gateway, and a server. The sensor sends the encrypted data via the LoRa radio standard to a gateway in its vicinity, which forwards the data via LTE or LAN to the LoRa network server. Here, the data can be decoded, processed and sent for visualization and monitoring, e.g. to the database for natural swimming pools (DANA2.0).

As a result of the use of LoRaWAN, several advantages are available: the data transmission has a range of 2 kilometers in urban areas and 10 kilometers in rural areas. Due to the good build-ing penetration, the sensors can also be installed in shafts without any problems. Overall mainte-nance requirements are low, the sensors operate on batteries and have a potential lifetime of up to 10 years, depending on the transmission interval. In contrast to other transmission technologies, power consumption is also kept within limits - WLAN consumes about three times the power of a conventional LoRa sensor.

During data transmission, security is ensured by a device- and application-specific key, as well as a network-specific key. At Polyplan-Kreikenbaum, various LoRa-Systems have been developed for a variety of applications.

A standard LoRa-Set consists of an outdoor gateway and five sensors:

- Air temperature and humidity sensor
- Water level
- Water temperature
- Water meter
- Electricity meter

Depending on the project specification, further sensors can be connected, e.g. pH and turbidity sensors or further pressure sensors, electricity meters, etc. See Figure 1 (on page 13):
Functionality of data transmission via LoRa set

For monitoring purposes, the measurement data can be displayed in DANA2.0. See Figure 2 (on page 13): Data visualization of measurement data of LoRa sensors in DANA2.0

However, LoRa can be used not only to record measurement data, but also to transmit commands to individual devices. This can be used, for example, to switch plant components such as pumps remotely. For this purpose, the so-called LoRa switch was developed, which functions like an extended relay: it sends data such as the current consumption of a connected end device to the gateway and net-work server and can also receive and execute switching commands via a control dashboard. See Figure 3 (on page 13):
Functionality of data transmission via LoRa-Switch

The switch has various operating modes: in addition to a pure on/off function, it can switch in cyclic operation, which is either based on sensor data from the water treatment system or a fixed load parameter. In addition, it has a timer function by means of which a plant unit can be switched with-in a specific time window. Short-term further developments provide a fourth mode for switching when a freely selectable limit value is exceeded or undershot. In addition, the current power and the accumulated energy are displayed, which practically enables live monitoring of the consumer.
See Figure 4 (on page 13): LoRa-Switch

Overall, the use of LoRaWAN thus forms an alternative or supplement to conventional system con-trol and a further step towards the increasingly automated operation of water treatment in natural swimming pools. [PK]

Figure 1: Functionality of data transmission via LoRa set

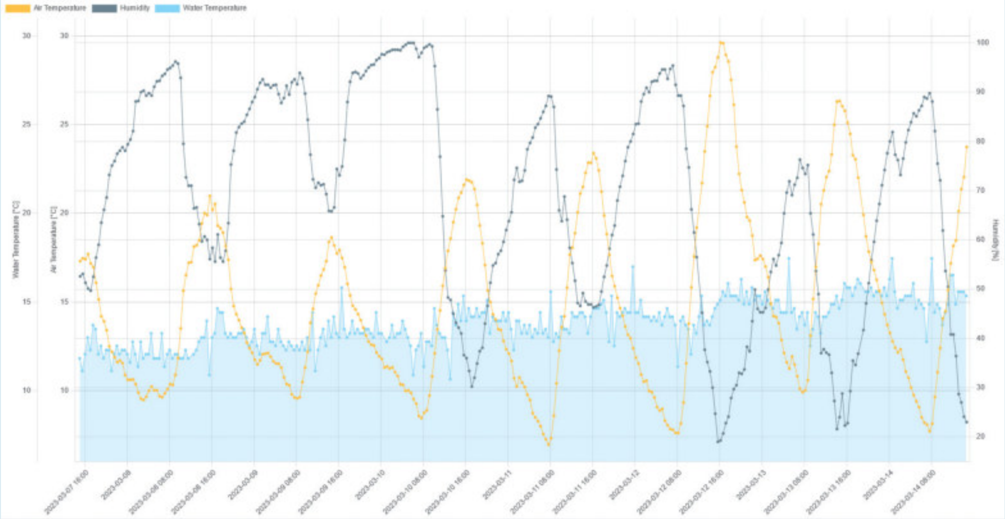


Figure 2: Data visualization of measurement data of LoRa sensors in DANA2.0

Figure 3: Functionality of data transmission via LoRa-Switch

Figure 4: LoRa-Switch - Photo: PK

Biology

Film growth in a natural pool

Investigation of film growth in a natural pool with biotechnological water treatment during pool operation

Inducement

In natural outdoor pools, especially if the pools are sealed with foil or other smooth surfaces, the natural biological growth on the walls and other surfaces is perceived as disturbing. Brown-green stains on the walls are considered an aesthetic and quality-reducing impairment in a pool that is visually more like a conventional, chlorinated outdoor pool. In addition, the biofilm growth, especially on the smooth surfaces of the steps, can pose a high risk of slipping for bathers. In many pools, there are also lime scale deposits on the walls. See Figure 1.

The cleaning effort for pool staff is therefore very high, especially in foil pools. The development of technical cleaning devices, which partly relieve and facilitate the work of the bathroom staff, is progressing steadily. However, in addition to the cost factor, the devices also require intensive care and maintenance.

The question therefore arises as to whether there are possibilities to prevent the development of the growth in other ways that are compatible with natural swimming pools.

As part of a research project funded by ABS (KLS Gewässerschutz GmbH & Polyplan-Kreikenbaum Gruppe GmbH), the first step was therefore to microscopically examine the composition of such a film growth in a natural outdoor pool with a high circulation rate (water exchange approx. 4 ml per day) during ongoing operation in the 2022 bathing season.

For the growth experiment, two pieces of foil were exposed at suitable locations in the pool. The foil used was the same as that used to line the pools. This was an FPO film (flexible polyolefin). One film was cleaned regularly as in normal operation (GF = Cleaned Film), the second film was not cleaned (NGF = Non-Cleaned Film). Once a month, from May to September, a piece was cut out of each film and sent to KLS Gewässerschutz in a preservation solution for microscopic analysis. The film growth was evaluated qualitatively and quantitatively.

Film growth over the course of the year

Foil growth increased over the course of the season on both the uncleaned foils (NGF) and the cleaned foils (GF). The following images are photo examples of both films (cleaned and not cleaned) from the months of June and September. With the naked eye and at low magnification in the binocular (approx. 10 - 50x), three different coatings were visible on the films: dark brown coatings or crusts, white lime precipitates or crusts and olive-green coatings. In addition, filamentous algae (green and white) grew on the foils, protruding vertically upwards or lying in bundles on the foil. Occasionally, chironomid larvae (midge larvae), snails and snail spawn settled on the film.

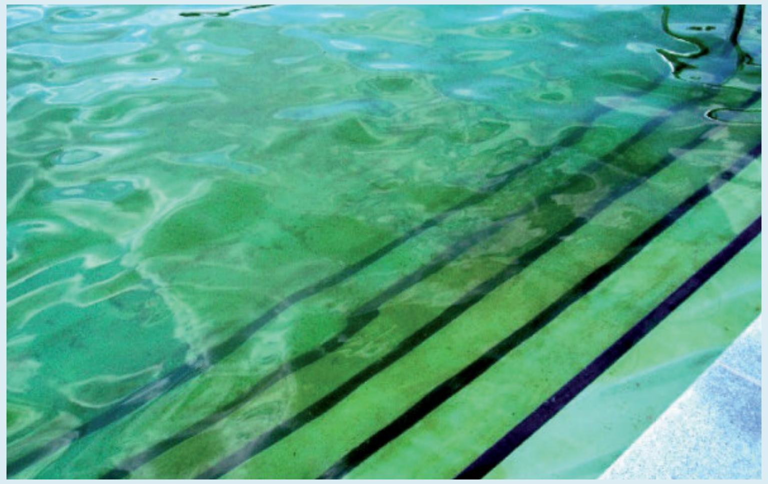


Figure 1: Typical brown-green fouling in a natural outdoor pool with foil sealing. - Photo: KLS

Types of algae and biomasses encountered

In the growth samples of the cleaned and non-cleaned foils, benthic species from the groups of blue-green algae, diatoms, green algae, ornamental and yoke algae as well as yellow-green algae were found (Table 1). This was dominated by algae that form bearings and/or filaments. The deep-brown coatings were never diatoms, but always blue-green algae forming bearings and filaments. The olive-green coatings were formed by blue-green algae, green algae, yellow-green algae and ornamental and yoke algae.

The total biomass or biovolume of algae was lowest on both foils in May and highest in July (Figure 15). In general, the colonisation density was significantly higher on the uncleaned films, but from July onwards, the cleaned film also showed stronger growth.

The visual assessment of the colonisation density of the films by the naked eye differed from the actual amount of biomass (= biovolume) of living algae determined under the microscope. The total biomass ranged from 0.002 to 0.17 mm^3/cm^2 on the cleaned foil (GF) and from 0.06 to 0.27 mm^3/cm^2 on the uncleaned foil (NGF).

Depending on the month, green algae, ornamental algae, yoke algae or blue-green algae accounted for the largest proportion of the total biomass of the benthic growth. Diatoms and yellow-green algae were only present in small quantities or not at all. From June onwards, increasing lime precipitation took place on the cleaned and especially on the non-purified foils. The hardness of the pool, clean and filling water in the natural outdoor pool can be classified as „soft“ to „medium“ with values between 1.4 and 2.0 mmol/L. The strong lime precipitation is therefore not due to a particularly high hardness of the water, but rather to bioaccumulation. The strong lime precipitations are therefore not due to a particularly high hardness of the water, but rather to the biogenic decalcification by the growth of algae.

The lime crystals occurred individually, but predominantly as accumulations in and around the cell stores of the blue and green algae. The green algae genus Coleochaete and the blue-green algae species Homoeothrix crustacea are known to form camps or cell walls that are heavily incrusted with lime. From July onwards, the uncleaned foil was almost completely coated with white lime precipitation, which increased in thickness towards September. According to a rough visual estimate, at the end of the season (September) about 60-70% of the cover on the uncleaned foil was lime, the remaining 30-40 % was vegetation.

Many of the species found indicate an oligotrophic, organically unpolluted water body, which also applies to the natural outdoor pool. The occurrence of current-loving species on the foils also indicates an increased current. Since the foils were attached in the immediate vicinity of an inflow nozzle and a skimmer outlet, a relatively high current can indeed be assumed in this area. The increased flow in this area presumably promotes the growth of benthic communities or biofilms („eutrophic effect of the flow“). Increased flow velocity leads to a reduction in the nutrient-depleted boundary layer. This is associated with a shortening of the diffusion paths and an improved supply of nutrients to the organisms. This phenomenon could be an explanation for the fact that, despite the oligotrophic conditions in the body of water of the bath, sessile algal coverings and other biofilms are able to supply themselves sufficiently with food and form correspondingly high biomasses. Blue-green algae are bacteria capable of photosynthesis, so strictly speaking they do not belong to the group of algae, but to the group of cyanobacteria. Cyanobacteria are capable of forming toxins under certain circumstances. The frequent occurrence of blue-green algae or cyanobacteria in the benthic growths in the natural outdoor swimming pool can be considered harmless at the existing biomasses of a maximum of 0.06 mm3/L. Only from cyanobacteria biovolumes >1 mm3/L is „increased attention“ required according to the „Recommendation for the Protection of Bathers from Cyanobacteria Toxins“ by the Federal Environment Agency. [KLS]

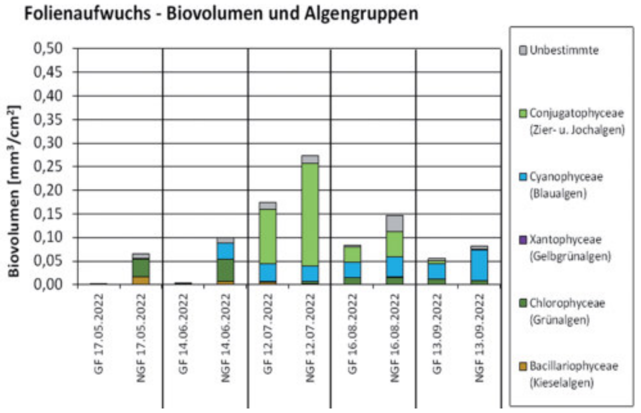


Figure 15: Biomasses or biovolumes (mm^3/cm^2) of benthic algae on the cleaned (GF) and not cleaned foil (NGF)

Blaualgen (Cyanophyceae)	**Kieselalgen (Bacillariophyceae)**	**Grünalgen (Chlorophyceae)**
unbestimmte Chroococcales (einzeln)	Achnanthes sp.	Lager fädiger Grünalgen, Zellen polygon, in Reihen (vermutlich überwiegend Coleochaete sp.)
Clastidium setigerum	Cocconeis sp.	cf. Klebsormidium sp.
Lager unbestimmter Chroococcales (braun, olivgrün, goldgelb)	Cymbella sp.	cf. Cladophora sp. / Rhizoclonium sp.
Calothrix sp. (grün, olivgrün)	Diatoma sp.	Ulothrix sp.
Blaualgen-Lager mit Fäden (ev. Homoeothrix od. junge Calothrix)	Fragilaria sp., Fragilaria crotonensis	Oedogonium sp.
Komphophoron schmidlei	Gomphonema sp.	Stigeoclonium sp.
Pseudanabaena catenata	Nitzschia intermedia	
Nostoc sp. ("Gelkugeln")	Rhoicosphaenia sp.	
Zieralgen und Jochalgen (Conjugatophyceae)	**Gelbgrünalgen (Xanthophyceae)**	**Unbestimmte**
Cosmarium sp.	Tribonema sp.	Spore groß (10 - 15 µm)
Spirogyra sp.		Spore klein (5 - 10 µm)
Zygnema sp.		braune Spore
Mougeotia sp.		

Table 1: Growth species or groups found and counted on the slides. (Note: according to the latest systematics, *Klebsormidium* belongs to the *Klebsormidiophyceae* and not *Chlorophyceae*)

Foils in June 2022

Figure 2: 14.06.2022: Foil cleaned (GF): left: Original view
right: magnifying glass view (approx. 15x magnif.)

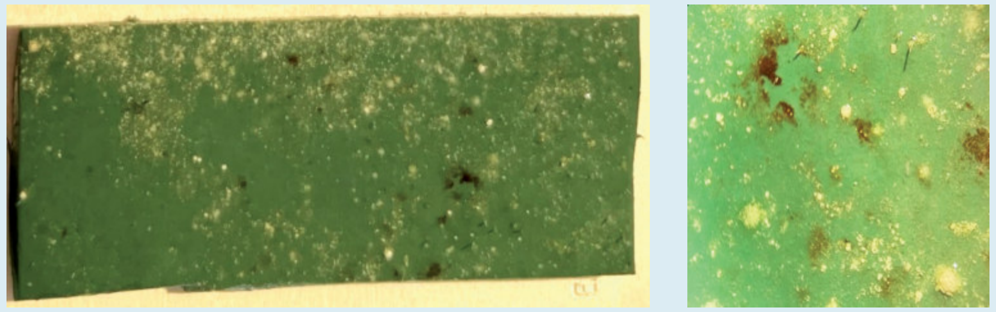


Figure 3: 14.06.2022: Foil not cleaned (NGF): left: Original view
right: magnifying glass view (approx. 15x magnif.)

Figure 4: 14.06.2022: Foil not cleaned (NGF): Coatings of calcareous precipitates, brown crusts and green filamentous algae, occasionally also chironomid larvae (45x magnif.)

Foils in September 2022

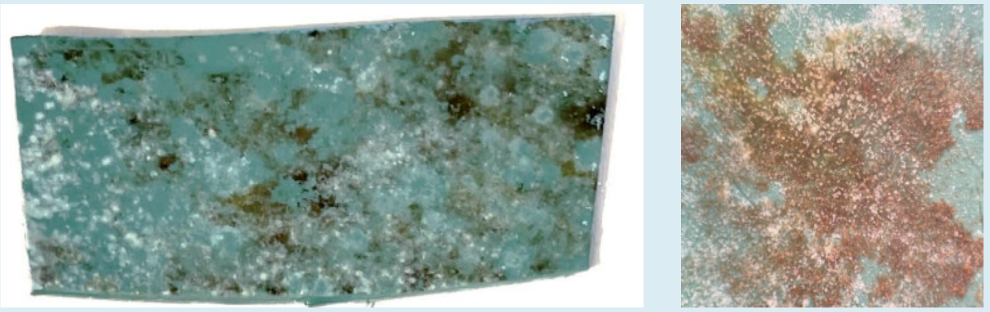


Figure 5: 13.09.2022: Foil cleaned (GF): left: Original view - right: magnifying glass view (approx. 35x magnif.). Coatings of brown crusts and lime precipitates.

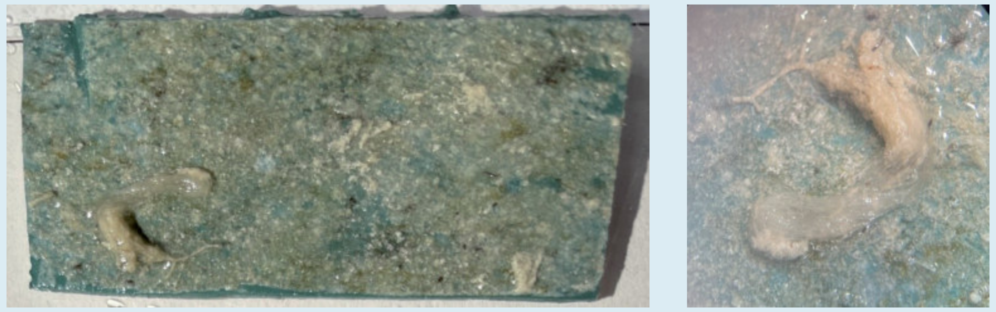


Figure 6: 13.09.2022: Foil not cleaned (NGF): left: Original view - right: magnifying glass view (approx. 45x magnif.). Coatings of calcareous precipitates, predominantly green coatings and bundles of dead, filamentous algae. - All images: KLS

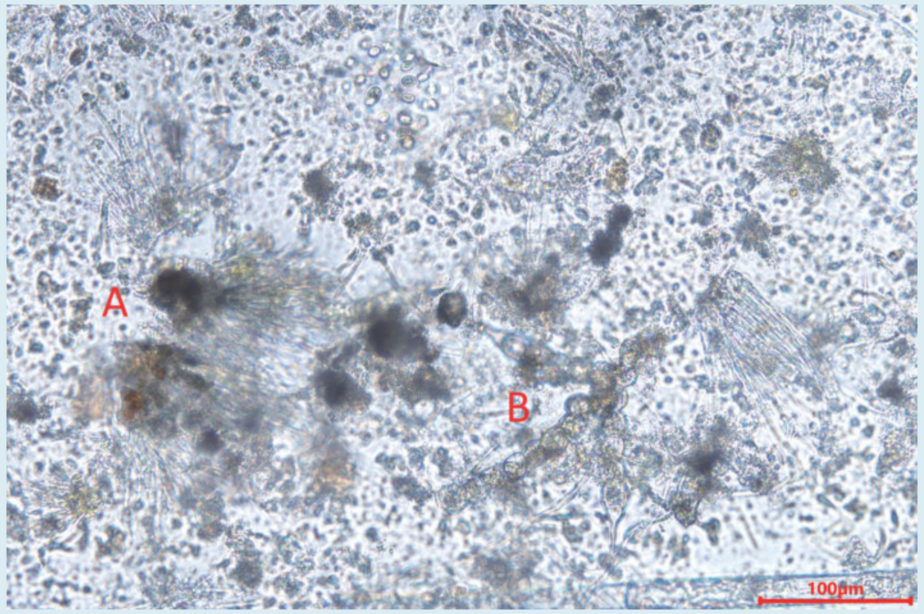


Figure 7: „Typical“ microscopic image of the growth community. The „hair tufts“ (A) are filament-forming blue-green algae that grow from beds and are partly encrusted with calcium carbonate. The „cell chain with extended hairs“ (B) is a filament-forming green algae, which also grows up from lagoons and can store calcium. Cleaned foil on 13.09.2022, sample diluted 1:2 (light microscope image, approx. 200x magnification) All images: KLS

Figure 8: Blue-green algae of the genus *Calothrix* were present in every sample of the uncleaned foils from June onwards (left: 14.06.; middle: 12.07.; right: 13.09.2022; approx. 400x magn.)

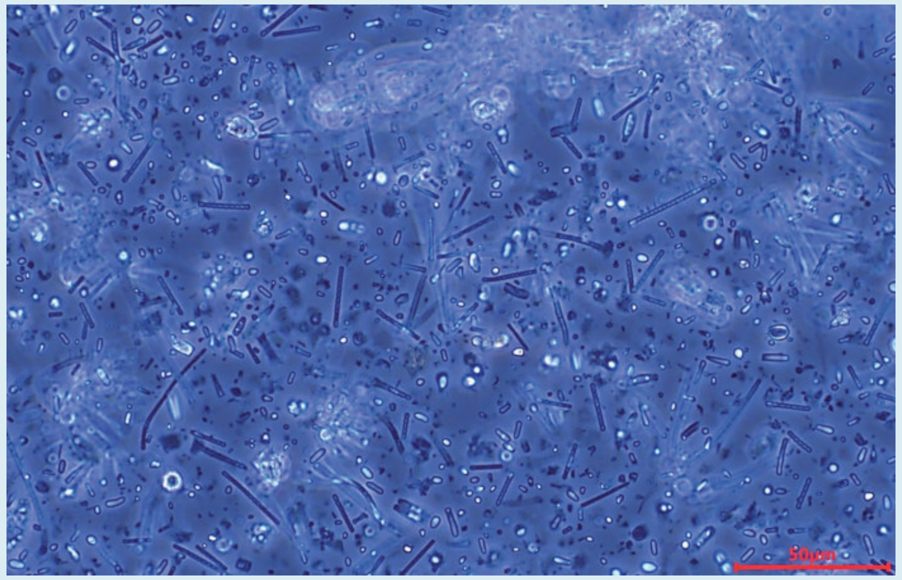


Figure 10: Undetermined blue-green algae: Hormogonal (filament-forming) and chroococcal (single, round-oval) GF, 12.07.2022; approx. 400x magnification, phase contrast)

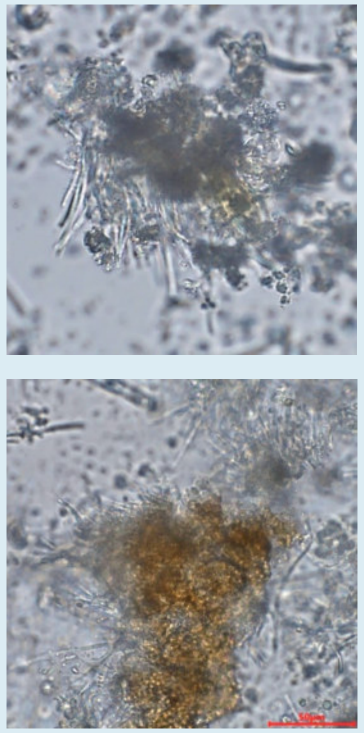


Figure 9: Blue-green algae presumably of the species *Homoeothrix crustacea* were present in every sample from June onwards (approx. 400x magnification)

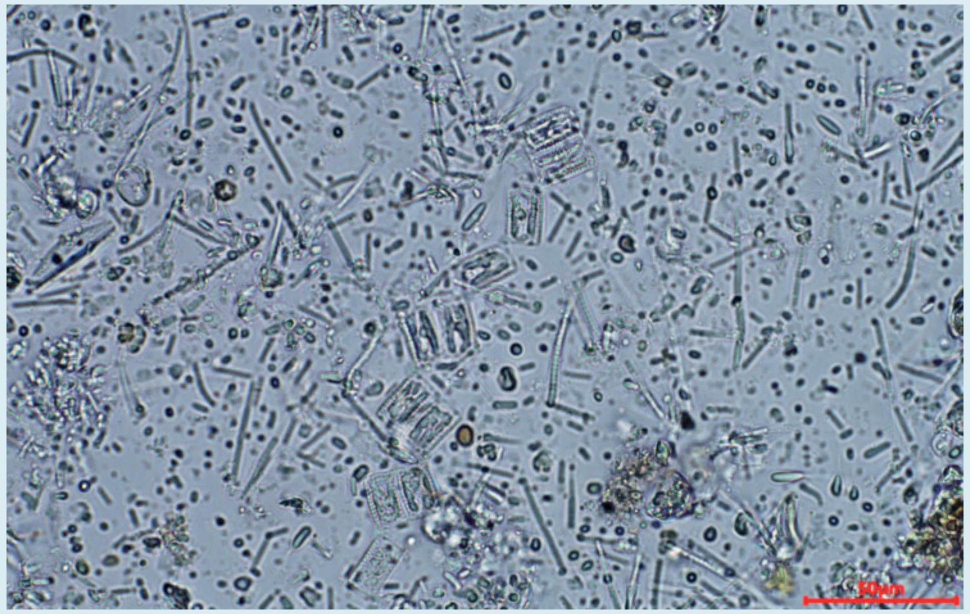


Figure 11: Diatom chain of the genus Diatoma surrounded by numerous chroococcal and hormogonal blue-green algae (GF, 12.07.2022; approx. 400x magnification).

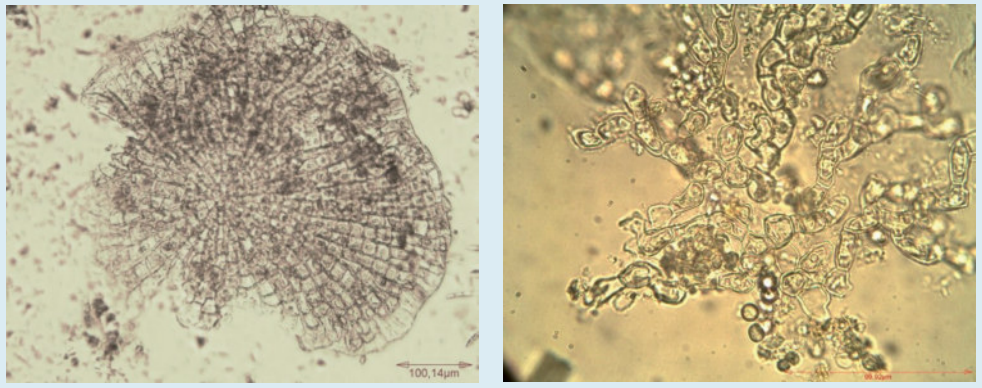


Figure 12: Deposit of the green algae *Coleochaete* (left: NGF, 17.05., 125x magnification; right: GF, 17.05., approx. 500x magnification.).

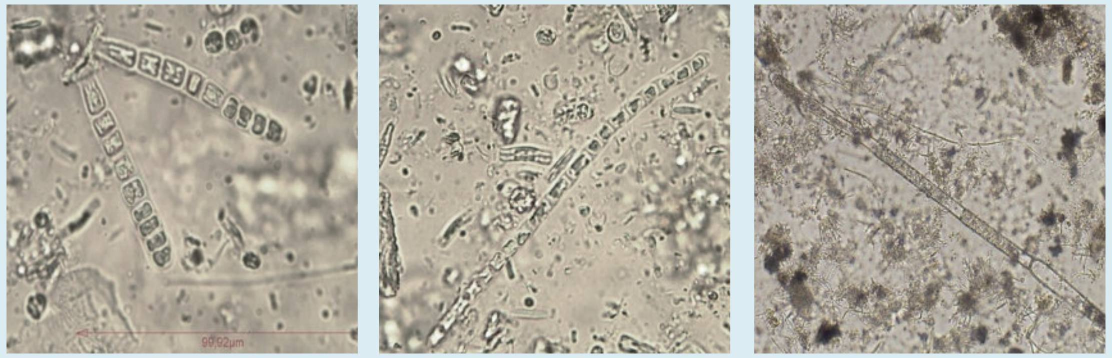


Figure 13: Filamentous algae from different groups of green algae: left: *Ulothrix sp.* (NGF 17.05., 500x), middle: cf. *Klebsormidium* (NGF 17.05., 500x), right: *Oedogonium sp*. (GF 16.08., 200x).

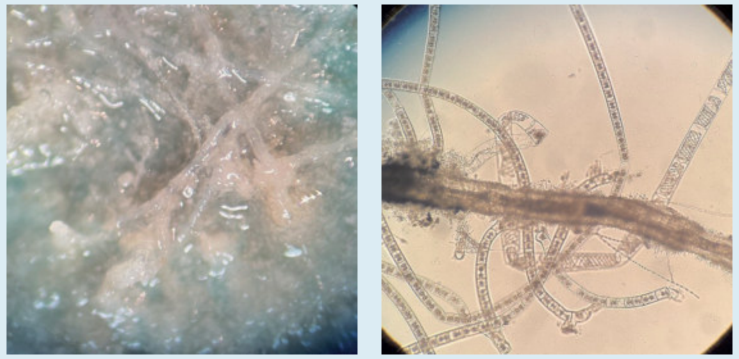


Figure 14: Filamentous yoke algae: *Spirogyra sp.* and *Zygnema sp*. on dead filamentous algae of the genus