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ULTRAVIOLET LIGHT AS AN ADDITION TO CURRENT WATER TREATMENT METHODS AT PORI CENTRAL SWIMMING HALL

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ABSTRACT

The purpose of this thesis was to see how ultraviolet light-treatment can improve water disinfection at Pori central swimming hall. The swimming hall has already an option for ultraviolet disinfection system, but there hasn't been any immediate need for it to be utilized in combination with more conventional water treatment methods.

Nevertheless, growing visitor numbers are already straining the swimming hall's water treatment systems and some improvement was hoped. Demand for good quality swimming water increases with growing visitor numbers.

By using ultraviolet light treatment, as assisting advanced water treatment method, the swimming hall would be able to offer even better quality swimming water. With ultraviolet reduction, can one of the water circulations be disinfected more thoroughly, and due to water mixing between different pools can the ultraviolet treatment system reduce the amount of microbes found in all the pools.

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VEDENKÄSITTELYN TEHOSTAMINEN UV-VALOLLA PORIN KESKUSTAN UIMAHALLISSA

Valtonen, Jukka
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Avainsanat: Ultravioletti säteily, vedenkäsittely, uimahalli

TIIVISTELMÄ

Tämän työn tarkoitus oli nähdä miten ultravioletti valon lisääminen vaikuttaa Porin keskustan uimahallin veden käsittelyyn. Keskustan uimahalliin on jo rakennusvaiheessa lisätty optio ultravioletti puhdistukselle, mutta sille ei ole vielä ollut pakottavaa tarvetta, koska nykyiset puhdistusmenetelmät ovat toimineet kuten pitävät. Todellisuudessa, nousevat kävijämäärät laittavat nykyiset puhdistus-menetelmät koville ja parannusta on kaivattu henkilökunnan puolesta. Vaatimukset vedenlaadulle nousevat kävijämäärien kasvaessa.

Ultraviolettia käyttävän puhdistuksen käyttäminen, avustavana vedenlaatua parantavana vedenkäsittely metodina, keskustan uimahalli voisi tarjota vielä laadukkaampaa uimavettä sen käyttäjille. Ultravioletti puhdistuksella, voisi puhdistaa tämän hetkisillä putkituksilla käyttää yhteen veden kierroista, ja johtuen veden sekoittamisesta eri kiertojen välillä, voi ultravioletti puhdistus parantaa vedenlaatua kaikissa altaissa.

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1 REQUIREMENTS SET BY AUTHORITIES

1.1 Requirements Set By Authorities

Poor swimming water quality can cause major health issues to people, and that’s why authorities have set strict limits concerning the water quality. Public swimming halls must be designed and maintained so, that they won’t cause any health issues to people using it. According to The Social Welfare and the Ministry of Health Regulation 315/2002, the swimming hall water must be inspected regularly to ensure that quality standards are met. In addition to this, the maintenance staff must ensure the quality by routine checkups stated in the swimming halls own inspection manual. In extreme cases, the swimming hall can be closed, if the quality requirements are not met (1, p. 1-2). In Pori central swimming hall, chlorine- and pH-levels are measured constantly and automation informs the staff to action, if the levels are not in acceptable range.

1.2 Requirements by Users and Staff

Swimming must be pleasant and healthy experience to the user. Water should be aesthetically clean and transparent, and it shouldn’t smell or taste bad. Water should not be allowed to be a carrier of any contagious diseases. Staff spends most of their time in the swimming hall, thus the air should also be as clean as possible

2 WATER TREATMENT IN FINLAND'S SWIMMING HALLS NOWADAYS

There are approximately 250 swimming halls or bath houses in Finland (2). Oldest of our swimming halls are constructed in 1940's and actual bath houses began emerge in the 1980's. Currently the 1970's swimming hall's are under renovation or being replaced by new ones.

3 IMPURITIES IN POOL WATER

Largest contributors on water quality decrease are the swimmers themselves. Swimmer carry number of impurities on their body like hair, skin cells, urea, sweat, cosmetic products, textile fibers and bacteria. Swimming halls equipped with massaging water streams and whirlpool baths, increase the load even more. Largest environmental impurity to inside pool is dust, and outdoor pool also affected with leafs, seeds, branches and sand. (3, p.20).

4 WATER PURIFICATION AT PORI CENTRAL SWIMMING HALL

4.1 Water Pumping, Filtering and Rinsing

In order to keep the quality in acceptable levels, the water treatment must be continuous process. Treatments for swimming hall water are divided between basic and advanced treatment methods.

Basic treatments should be used in all swimming halls, and it provides a reasonable amount of purification. In lightly used swimming halls, basic treatments methods are usually sufficient. During high usage times, advanced methods are required to achieve the desired level of purification. (4, p. 5-6)

Basic treatment methods in a swimming hall include precipitation, rough and fine filtering, chlorification, pH adjustment, use of active carbon and the water heating. Rough filter can be placed either before the equalization pool or after the equalization pool before the pump.

Advanced treatment methods in a swimming hall include ozonation, active carbon filtration, ion exchange and UV-light. These methods provide extra treatment if basic methods aren’t sufficient enough.

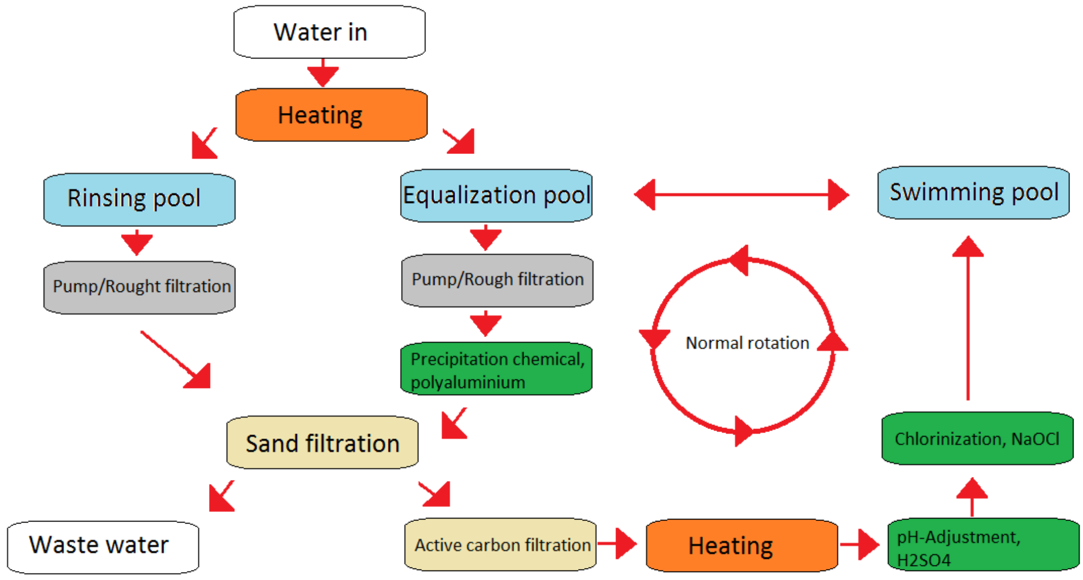

Figure1 One of the water circulations at Pori central swimming hall.

Pori central swimming hall has active carbon filtering added as an advanced water purification system. Other Advanced water purification systems include ozonation, ion exchange and UV-light. Pori central swimming hall has a readiness for UV-filtration added on the construction phase.

4.1.1 Rough Water Filtering

Pori central swimming hall has ten circulation pumps, each equipped with their own basket filter. These basket filters remove particles over 3mm in diameter from the water. These basket filters are made of reinforced plastic.

Figure 2 Red circulation pump and the gray basket filter.

4.1.2 Precipitation

Precipitation is closely tied with filtering. Right amount of precipitation chemical is needed to achieve best filtration. There are multiple choices of precipitation chemicals on the market, and most of them have aluminum as the active substance. The precipitation chemical form flocks when in contact with organic matter, these flocks are then large enough to be removed with filtering. Without the flocking, these small particles would just pass the filtration system. Precipitation makes it possible to remove micro-organisms from the water that are resistant to chlorine.

The precipitation chemical needs to be fed directly in to the water flow, and it needs to reach the filter in less than 10 seconds. If fed too early in the process, flocks starts to emerge before reaching the filter. This event can be harmful to pipes and it also reduces the filtration effect. To prevent pipe clogging, there should not be any valves or other devices between the feeding point of the chemical and the filter. Precipitation should be used at least during heaviest pool use if not automated.

4.1.3 Chlorination

In order to keep the microbiological water quality levels under control, the water needs to be chlorinated. This causes problems to staff and swimmers. When chlorine reacts with impurities in the water, several volatile and unhealthy compounds are formed. People near the water are subjected to these compounds. Most dangerous of these compounds are chloramines, trihalomethanes and chloroacetic acids. Some of these compounds can cause cancer, liver failures and asthma. Milder side effects include respiratory problems and eye-irritation. (5, p.11.)

Chlorine is present in two forms, bound and free chlorine. When chlorine is added to the water, it reacts with impurities forming chloramines, which then changes to bound chlorine. After this stage the chlorine is no longer able to purify the water.

Free chlorine is chlorine that hasn't yet reacted with any organic nitrogen compounds and hasn't therefore transformed in to bound chlorine. Free chlorine destroys bacteria and viruses from the water. Sufficient amounts of chlorine should be present all the time to maintain disinfection activity. If the pool has too little amounts free chlorine ,or none at all, algae starts to form, bacteria count goes up and the water becomes dim.

Swimming pools have an on line filtration process. With a well planned water purification methods, filtration, precipitation, it's possible to remove most large part of the impurities and majority of the bacteria. With membrane filtration, most of the viruses can be removed from the cycle. With well planned filtration and precipitation, need for chlorification and consumption chlorine goes down. This doesn't mean that you can totally give up chlorine use, because other methods don't help in the pool itself. Swimming water should always contain free chlorine to prevent infectious diseases from transmitting from one swimmer to another.

The disinfectant chemical used at Pori central swimming hall is sodium hypochlorite ($NaOCl$). The hypochlorite is manufactured in situ, with a chlorine maker, from salt and water. The solution produced, with the chlorine maker, is directed to a feeding tank, from which it’s directed to water circulation with chemical pumps. Chemical pumps used there are diaphragm pumps.

The chlorine maker works as an independent unit, which produces the needed levels of sodium hypochlorite. Operators only need to makes sure that there is enough salt in the salt feed tank. Otherwise, the machine is totally automated.

Figure 3 Chlorine production at its natural habitat.

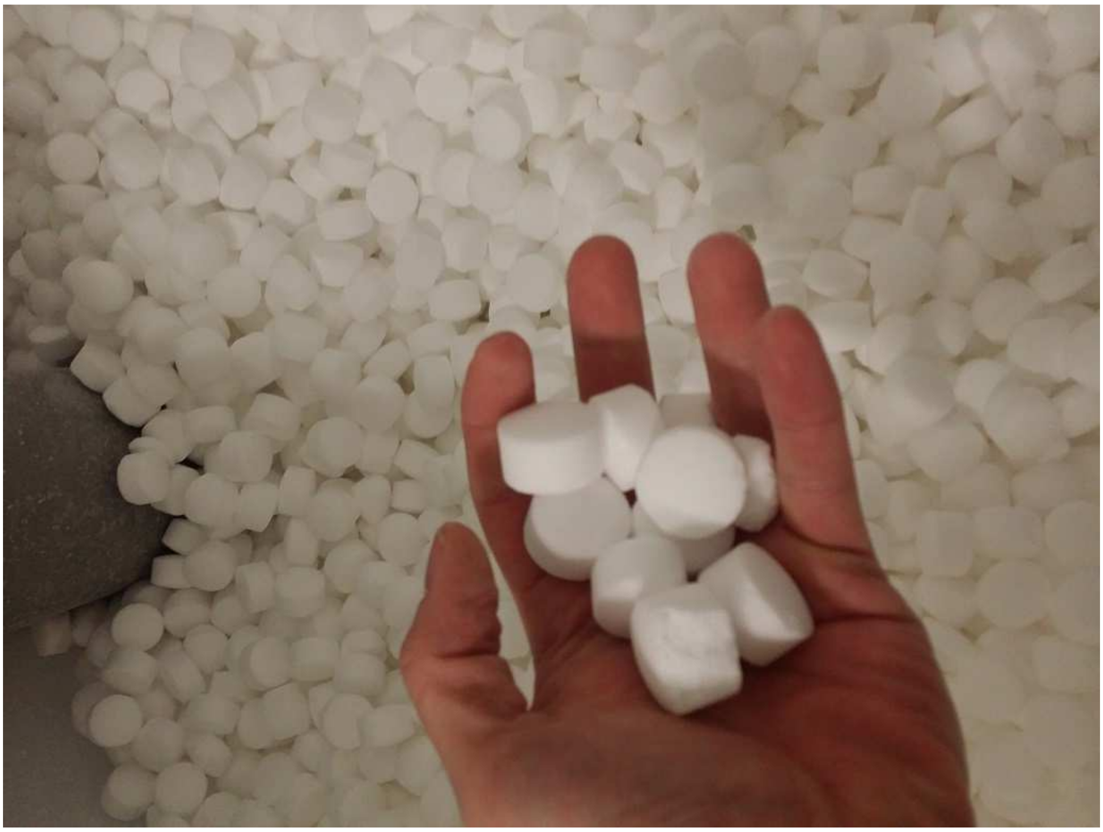

Figure 4 Large salt (NaCl) grains that are fed to the chlorine producer.

4.1.4 Water Pumping

Water pumping in the Pori central swimming hall is maintained with ten frequency transformer controlled circulation pumps. In addition to this, the active carbon filters have two pumps and there’s also one more providing the rinsing water. Larger pumps can provide a flow of 125m^3/h and the smallest goes up to 15m^3/h. There are also several other pumps in the swimming hall, but they are essential for the water purification system.

4.1.5 Sand Filtration

For the sand filtration, Pori central swimming hall uses pressure sand filters. Before every sand filter, there is a feed of precipitation chemical in to the water, in this case polyaluminium chloride. There are ten sand filters in use at the swimming hall, eight of them have an surface area of 4,9m^2, and two smaller ones have 4,3m^2 and 0,79m^2. All the filters are filled with 0,9 meters of filtration sand and 0,4 meters of anthracite. Height of these filter vary from 3,5m to 2,5m for the smallest. Filtration speed is about 25 meters per hour and it can be adjusted if needed.

Each of the filters are equipped with seven electronically controlled valves, which allows normal rinsing to take place, but also they provide means to perform the air rinsing, counter current rinsing and downstream rinsing. In normal mode, there’s only two valves open, one on the top for the incoming water and one down at the bottom to let it out after the purification has taken place.

Figure 5 Large sand filter (behind) and blue valves connecting to it.

4.1.6 Filter Rinsing

Filter rinsing is a crucial part of the water purification. Sand filters get clogged from small particles they catch and of the precipitation chemical that creates a small film on top of the sand. For the rinsing there is a circulation pump and an air compressor. Water used for the rinsing, is directed from a separate rinse water pool. This water is circulated with the equalization pool to keep it changing.

The rinsing takes place as follows

4.1.7 Sand Filtration Treatment Stages

Stage	Action
Preparation for the rinsing	Automation checks that there is enough water in the rinsing pool and that the buffer pool before the sewer has enough room in it to hold the used rinsing water. Pump for the filter is shut down, and the water circulation through that filter stops. All valves used for this unit close.
Lowering the water level in the filter	Air valve on top of the filter open. Water escape valve is opened. Water escapes to the bumper pool before entering sewer. After the water is removed, all the valves close.
Air purge	Purge air valve, the air on top opens and air compressor is started. Air purge will stay on according to a set time. After the purge, both valves close and the compressor is shut down.
Preparation for the counter current rinsing	Rinsing water valve is opened and the pump used for rinsing stats. Flow rate and duration according to a set time. In this time, the filter is filled with water, top air valve closes and the waste water valve opens.
Counter current rinsing	After the waste water valve is completely open, the rinsing water pump starts to pump water in through the waste water valve. Flow rate and duration according to a set parameters.
Downstream rinsing	Rinsing water pump is shut down. Incoming and outgoing water valves are closed. Incoming and waste water valve is opened. Rinsing water pump is starts to pack, the sand in the filter, to its place. Flow rate and duration according to a set parameters.
Ending the rinsing	Rinsing water pump is stopped. All valves are closed
Returning to normal state	Pump for the rinsed filter starts. After the pressure has gone up, secondary circulation (active carbon & heating), chemical and sample water pumps are started.

4.2 Active Carbon Filtering

Active carbon filtering is necessary to keep pool waters bound chlorine and organic compound levels at acceptable levels. Swimming hall at Pori central has two active carbon filters.

Active carbon filter one takes care of the deep end of the large swimming pool and half of the diving pools water. Water mixing in the equalization pool, with large and diving pool, allows the active carbon filter one to ease of the bacterial load from these pools. This filter operates with its own frequency controlled converter, this allows it to operate between loads of 40-100m^3/h. The flow though the filter should be smaller, than the load on the sand filter attached to the same pool flow. In reality, the flow is adjusted by following bound chlorine levels that the active carbon filter treats. After the treatment, water is returned to the cycle.

Rinsing of the filter is automated. Rinsing is similar to the sand filter, only difference being that active carbon filter doesn't have a pressurized air rinsing. Normal rinsing is therefore performed with counter-, and downstream rinsing with water taken from the rinsing pool.

Operational Stages of Charcoal Adsorption

Phase	Action
Preparation for the rinsing	Automation checks that there is enough water in the rinsing pool and that the buffer pool before the sewer has enough room in it to hold the used rinsing water. Pump for the filter is shut down, and the water circulation through that filter stops. All valves used for this unit are closed.
Counter current rinsing	Ingoing and outgoing rinsing water valves open. Rinsing pump activates. Flow rate and duration according to a set parameters.
Downstream rinsing	Rinsing pump stops. Ingoing and outgoing rinsing water valves close. Ingoing and outgoing water valves open. Rinsing pump activates. Flow rate and duration according to a set parameters.
Rinsing ends	Rinsing pump stops. Outgoing water valve closes
Returning to normal state	Outgoing water valve opens. Circulating pump activates. System returns to normal state

Figure 6 Air compressor used in rinsing.

4.3 Weekly Maintenance

Weekly maintenance brake is currently situated between Wednesday evening and Thursday morning, hence the oddities in the opening hours.

4.3.1 Manual Cleaning

On Wednesday evening, the smaller and irregularly shaped pools are vacuumed by hand with a special vacuum cleaner that uses water pressure to push small particles to the “dust bag”. After vacuuming, the “dust bag” is emptied, rinsed with high pressure water flow and left to dry.

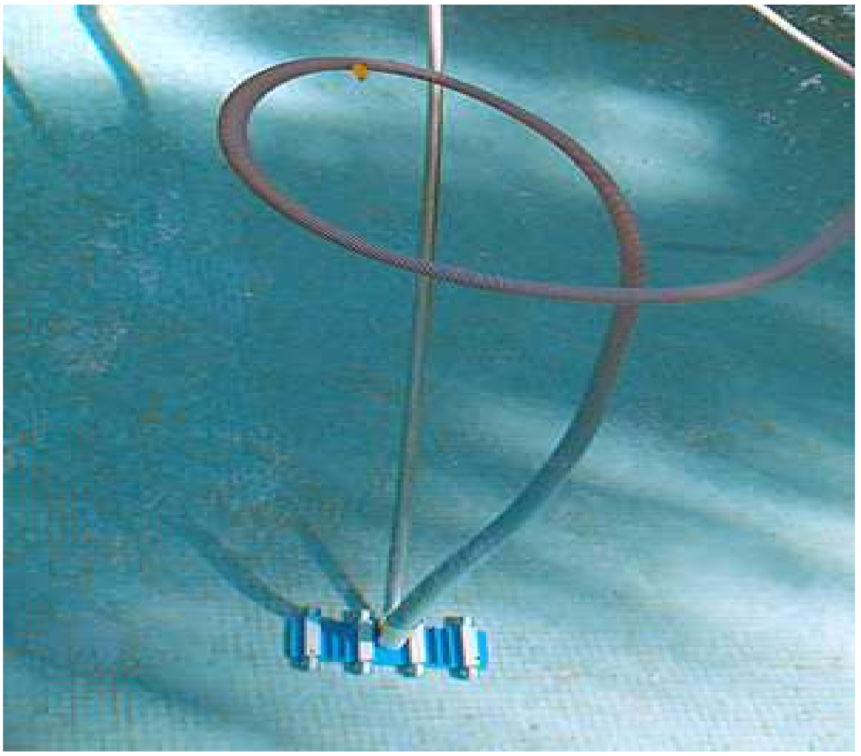

Figure 7 Manual vacuum. Picture from:
http://www.swimmingpool.com/sites/default/files/pool-vacuuming.jpg

4.3.2 Automatic Cleaning

Also on Wednesday evening, the three robotic vacuum cleaners are dropped in to the pools. These automatic cleaner will perform the cleaning of larger and more regularly shaped pools. This procedure will take hours and is continued on Thursday morning on places that are inaccessible by the robots normal cleaning path, like the steep rise to the shallower end of big pool.

Figure 8 Robotic cleaner parked.

4.4 Water Sampling

Environmental authorities require weekly monitoring of swimming hall water quality, but there are also chlorine and pH measurement devices on every pool that constantly monitor chemical levels of the water. These measuring devices take readings from overflow water leaving the pool. Tests required by the authorities are taken directly from the pools during weekly on Monday mornings and the reports are publicly displayed at the swimming hall cafeteria wall.

5 PLANNED UV-LIGHT WATER TREATMENT OPTION

Pori central swimming hall has a built in option for UV-light water treatment, this allows an easy upgrade to already efficient water purification.

Ultraviolet water purification lamps produce UV-C or “germicidal UV” radiation of much greater intensity than sunlight. The UV-C wavelength varies from 100 nanometers (nm) to 280 nm. Usually maximum radiation intensity is located at 254 nm. This allows the germicidal UV-C light to deactivate the DNA of bacteria, viruses and other pathogens, which leads to their ability to multiply and cause disease. UV-C light does this by causing damage to the nucleic acid of the microorganisms by forming covalent bonds between certain adjacent bases in the DNA. These bonds prevent the DNA from being unzipped for replication, thus making it unable to reproduce. Also, organisms subjected to UV-C light, will die when trying to reproduce. (6)

This advanced method is efficient and low in cost and generally has no impact on chlorine, VOC’s (volatile organic compound), heavy metals, and other chemical contaminants.

5.1.1 Ultraviolet Dose

Ultraviolet dose is commonly presented in millijoules/square centimeters, mJ/cm^2. Different micro-organisms require different amounts of the dose to be destructed. In the table below you can see some of the micro-organisms affected with ultraviolet treatment. (10)

Table 1 Required UV-Dose Amounts (mJ/cm^2) for Different microbe Species.

Species	Dose (mJ/cm^2)
Bacillus subtilis (spore)	12.0
Clostridium tetani	4.9
Legionella Pneumopholia	2.04
Pseudonomas aeruginosa	5.5
Streptococcus feacalis	4.5
Hepatitis A virus	11.0
Hepatitis Poliovirus	12.0
Saccharomyces cervisiae	6.0
Infectious pancreatic necrosis	60.0

Dose (mJ/cm^2)	Reduction in number of live microorganisms
5.4	90.0%
10.8	99.0%
16.2	99.9%
21.6	99.99%
27	99.999%

Calculation Example

Let's calculate what kind of flow rates we achieve with a closed tubular lamp assembly with length of 1.82 meters, 3.25cm effective radius around the 500w UV-lamp and 60.5L capacity. Diameter of the lamp inside the assembly is 16cm

Desired dosage: 30mW-sec/cm^2, for 99,999% E.coli microorganism reduction.

Efficiency of the lamp is 85%

Maximum UV-absorption for water is 75%

The lamp can produce about **105mW/cm^2** intensity to a range of five centimeters from the lamp. (9. p.9).

Now we can calculate the **effective average intensity**.

105 mW/cm^2 * efficiency * Maximum UV-absorption= **67 mW/cm^2**

By using the equation below maximum flow rate can be calculated (10.):

Dosage = effective average intensity * retention time

Due to high effective average intensity and long assembly, we assume the retention time to 1 second.

Now we have to calculate the volume flow.

Effective cross sectional area equals cross sectional area of the pipe(D = 225 mm) minus cross sectional area of the UV-tube (D= 160 mm):

$$A_{eff} = 398 \text{ cm}^2 – 201 \text{ cm}^2 = 197 \text{ cm}^2$$

Length of the UV-tube was 1820 mm ➔ effective volume around the tube. which is passed by the water, is :

$$V_{eff} = A_{eff} \text{ x } L = 1.97 \text{ dm}^2 \text{ x } 18.2 \text{ dm} = 35.8 \text{ dm}^3 = 35.8 \text{ L}$$

This means that volume flow could be max 36 L/s.

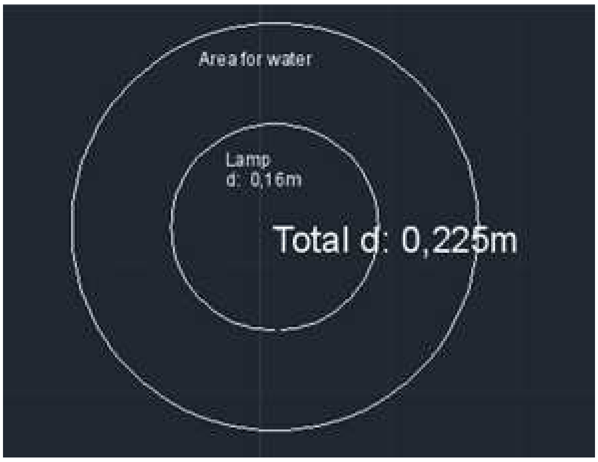

Figure 9 Visualization of UV-radiation chamber with tube and pipe dimensions.

Maximum accepted velocity of water flow can be calculated according to the following way:

$$dV/dt = v\ A_{eff} \tag{1}$$

, where dV/dt = volume flow of water (= 3.6 L/s)

A_{eff} = effective area (= 197 cm^2)

velocity v can be solved:

$$v_{max} = 1.8 \text{ m/s}$$

Calculation is based on the installed UV-device and calculation examples on various sources handling similar cases.

6 CONCLUSIONS

Purity of swimming hall water should be guaranteed in order to avoid contamination of harmful pathogens. Special attention should be paid on the proper disinfection and filtration of the water. UV-radiation ensures good results in disinfection.
Contact time of water in disinfection and UV-zone must be sufficient in order to ensure effective removal of pathogens. As conclusion it can be stated that water purification treatments in Pori City swimming Hall is at good level.

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