# WASTEWATER DISINFECTION WITH PERACETIC ACID: BACKGROUND INFORMATION AND EXPERIMENTAL RESULTS

***Tero Luukkonen***

*PAC-Solution Ltd, Pasilankatu 2, FI-00240 Helsinki, Finland*

## Introduction

Relevance of wastewater disinfection

Wastewater disinfection is becoming constantly more important since poor environmental hygiene directly affects the health of millions of people globally. Additionally the water scarcity in many areas forces to reuse treated wastewater in for example agricultural irrigation, industrial uses and as potable water. In all these applications the hygiene of treated wastewater is crucial. Finally, also recreational uses of water resources (swimming, fishing, fountains etc.) put pressure to ensure sufficient water quality.

Typically the wastewater treatment processes are capable of reducing microbe amounts up to 98 % without specific disinfection processes (table 1).

Table 1

Bacteria removal or destruction by different treatment processes [1]

| Process | Percent removal [%] |
|---|---|
| Coarse screens | 0 - 5 |
| Fine screens | 10 - 20 |
| Grit chambers | 10 - 25 |
| Plain sedimentation | 25 - 75 |
| Chemical precipitation | 40 - 80 |
| Trickling filters | 90 - 95 |
| Activated sludge | 90 - 98 |

However, due to large initial amount of microbes present in the effluents this is not often enough to meet quality requirements. The requirements are expressed in terms of bacterial indicators such as total coliform bacteria, fecal coliform bacteria, *Escherichia coli* or *Enterococci*. Sometimes also viruses such as coliphages are used as indicators of microbial quality. Coliphages are a group of viruses infecting *E. coli* bacteria. They are approximately same size as pathogenic viruses (such as polio) and are thought to behave similarly in wastewater treatment processes thus being a good indicator. There are two types of coliphages: male ($F^+$) specific and somatic. Male ($F^+$) specific coliphages are DNA based viruses and they infect only *E. coli* with pili. Somatic coliphages are RNA based viruses and they attach directly to the cell wall. Practical difference is that male ($F^+$) specific coliphages are recommended as enteroviral indicators instead of somatic coliphages [2,3]. This is because male ($F^+$) specific coliphages are thought to only be found in feces [1].

Examples of quality requirement standards include European parliament directive 2006/7/EC [4] about bathing water quality and Russian Federation Water Code 2010 [5] about sanitary-epidemiological requirements for the protection of coastal sea waters from pollution. Table 2 summarizes these two standards.

Table 2

Comparison of water quality standards in EU and Russia for coastal waters.

| Standard | Indicator organisms | | | |
|---|---|---|---|---|
| | Intestinal Enterococci | Total coliform bacteria | E. coli | Coliphages |
| EU Directive 2006/7/EC | 185 cfu/100 ml * | – | 500 cfu/100ml * | – |
| R.F. Water Code 2010 | – | 1000 cfu / 100 ml | 100 cfu/100 ml | 10 pfu/100 ml |

## Disinfection technologies

Currently, the selection of available wastewater disinfection methods is large. Widely used chemical and physical methods include chlorine (gaseous and hypochlorite salts), chlorine dioxide, ozone and ultraviolet radiation (UV). In addition there are also many methods which are being studied but are not yet commercially available: for example the use of high energy gamma rays [6]. Although the disinfection methods employed currently are generally successful in reducing the amount of pathogens there are some drawbacks. Chlorine, ozone and chlorine dioxide are known to produce harmful disinfection by-products (DBPs): for example trihalomethanes [7], bromates [8] and chlorates [9], respectively. Gaseous chlorine is also associated with safety risks. UV on the other hand is a safe technology from DBP and occupational hazards points of view. However, the disinfection efficiency of UV is very dependent on the water quality: UV transmittance (the amount of UV light passing through water) must be high and it is affected by turbidity, particulate matter and organics (COD and BOD). Low quality wastewaters also accumulate fouling materials on the sleeve-water interface in UV systems [10]. These foulants can be difficult to remove with mechanical and chemical cleaning systems. In addition UV disinfection can be highly energy intensive.

Peracetic acid (PAA) is relatively new wastewater disinfection method. However, PAA has been used as a disinfectant for a long time in beverage, food, pulp and paper industries as well as in hospitals. First studies employing PAA as a wastewater disinfectant were published in the 1980s [11 -13]. Since then PAA has become an accepted alternative to chlorine compounds, UV or ozone. There are currently full scale wastewater treatment plants (WWTPs) implementing PAA as a disinfectant operating in Finland and Italy.

PAA (chemical formula $CH_3COOOH$) is an organic peroxide with high oxidation potential. It is available as a ready-to-use equilibrium solution containing also hydrogen peroxide ($H_2O_2$), acetic acid ($CH_3COOH$) and water (see equation). As such, there are no safety hazards related to the on-site generation of chemical like with ozone or chlorine dioxide.

$$CH_3COOOH\ (aq) + H_2O \leftrightarrow CH_3COOH\ (aq) + H_2O_2\ (aq)$$

PAA has been shown to be effective in disinfecting especially secondary or tertiary wastewaters [14]. US EPA recommends PAA as one method for combined sewer overflow (CSO) disinfection as well [15]. Perhaps the most important advantage of PAA compared to more traditional disinfection methods is the lack of DBP formation [16-18]. Another advantage is that no re-growth of bacteria typically takes place after the application of PAA [19]. This is due to the disinfection mechanism of PAA: release of active oxygen and subsequent oxidation of metabolites [20]. As a comparison, the disinfection mechanism of UV has been shown to be somewhat reversible since bacteria can partly repair their damages caused for DNA structure [21, 22]. Table 3 presents a brief comparison of PAA, chlorine, chlorine dioxide, UV and ozone.

Table 3

Comparison of alternative wastewater disinfection methods

| | Peracetic acid | Chlorine | Chlorine dioxide | UV | Ozone |
|---|---|---|---|---|---|
| Investment costs | Low<br>Contact tanks | Low<br>Contact tanks | High<br>On-site generation<br>Contact tanks | High<br>UV lamps and chambers | High<br>On-site generation<br>Contact tanks |
| Operational costs | Moderate<br>Chemical consumpion | Low<br>Chemical consumption | Low<br>Electricity<br>Chemical consumption | Moderate<br>Electricity<br>Cleaning and lamp replace | Low<br>Electricity |
| Toxicity to microorganisms | High | High | High | High<br>Re-growth may be take place | High |
| Disinfection by-product (DBP) formation | No harmful DBPs detected | Significant problem<br>Chlorinated organics | Formation of DBPs can take place<br>Chlorates, chlorites | None | Formation of DBPs can take place<br>Bromates |
| Safety aspects | Relatively safe<br>Oxidizing<br>Corrosive | Serious risks with gaseous chlorine<br>Toxicity | Toxicity<br>Explosive | No serious risks | Toxicity |

Practical aspects of peracetic acid disinfection

PAA disinfection system requires the following components: chemical storage tanks, dosing pumps, on-line measurements, appropriate automation and a contact tank. Chemical storage system should have a ventilation system to allow release of pressure in case of emergency: if peroxides decompose as a result of e.g. catalysis by impurities they liberate oxygen gas which increases pressure. Dosing can be done with a regular diaphragm pumps. Tubing should be acid resistant steel, PTFE or PVC. PAA chemicals are corrosive as concentrated solutions but after dosing the concentration is diluted so that no corrosion or pH changes in wastewater takes place. On-line measurements are used as a basis of dosing. PAC-Solution Ltd has developed a disinfection system (PACS8) which utilizes flow and reduction-oxidation potential (ORP) in a novel way to regulate the chemical dosing constantly to the actual need. This allows to safe chemical. Finally, a contact tank is required to ensure sufficient contact time with wastewater and chemical. If WWTP has existing contact tanks for e.g. chlorine disinfection they can be used also with PAA. In addition, a discharge pipe can be used as a contact tanks as well. In some cases the time which wastewater spends in a discharge pipe can be 30 - 60 minutes which is sufficient.

Disinfection efficiency of peracetic acid

Comparison of peracetic acid and chlorine

Experimental set-up involved a bench scale batch reactor in which tertiary wastewater was treated with PAA. Contact times were simulated by stopping the disinfection reaction with sodium thiosulphate after specific time. *E. coli* was used as an indicator of microbial quality after treatment. Sodium hypochlorite and PAA were compared and results are shown in Fig. 1.

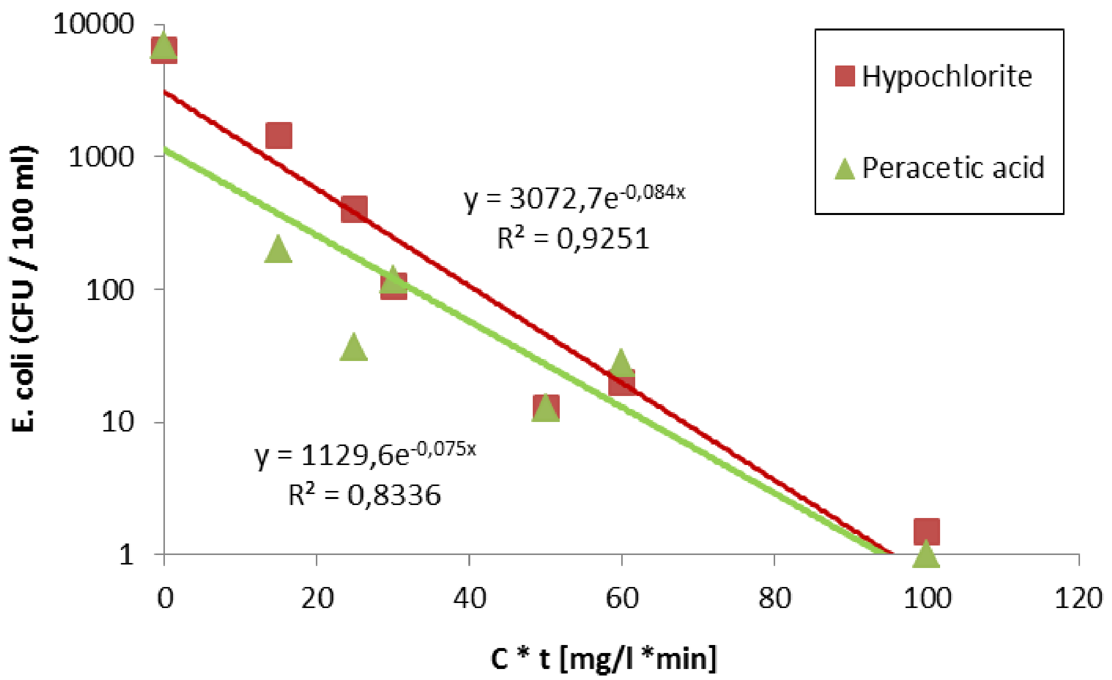


Fig. 1 – The comparison of hypochlorite and peracetic acid in disinfecting tertiary municipal wastewater.

As can be seen the disinfection efficiency of PAA and sodium hypochlorite are almost similar. However, when applying small doses and contact times PAA reaches almost 1 log better *E. coli* reduction. Both EU and Russian standards can be reached already with relatively small doses and contact times (see Table 2).

Peracetic acid in achieving Russian hygiene standards.

Figures 2 and 3 show the results for male (F+) specific *coliphages*, *E. coli* and total coliforms. As can be seen the coliphage limit (when considering the male (F+) specific coliphages) can be reached relatively easily. Similar results were obtained also for bacteria showing that the limits can be reached. The actual required dose and contact time are dependent on the water quality.

It can be concluded that PAA is suitable disinfectant for both secondary and tertiary wastewaters. Russian and European hygiene limits for coastal areas can be reached. PAA is also similarly effective when comparing to chlorine. However, the actual chemical requirement should be always determined at each site.

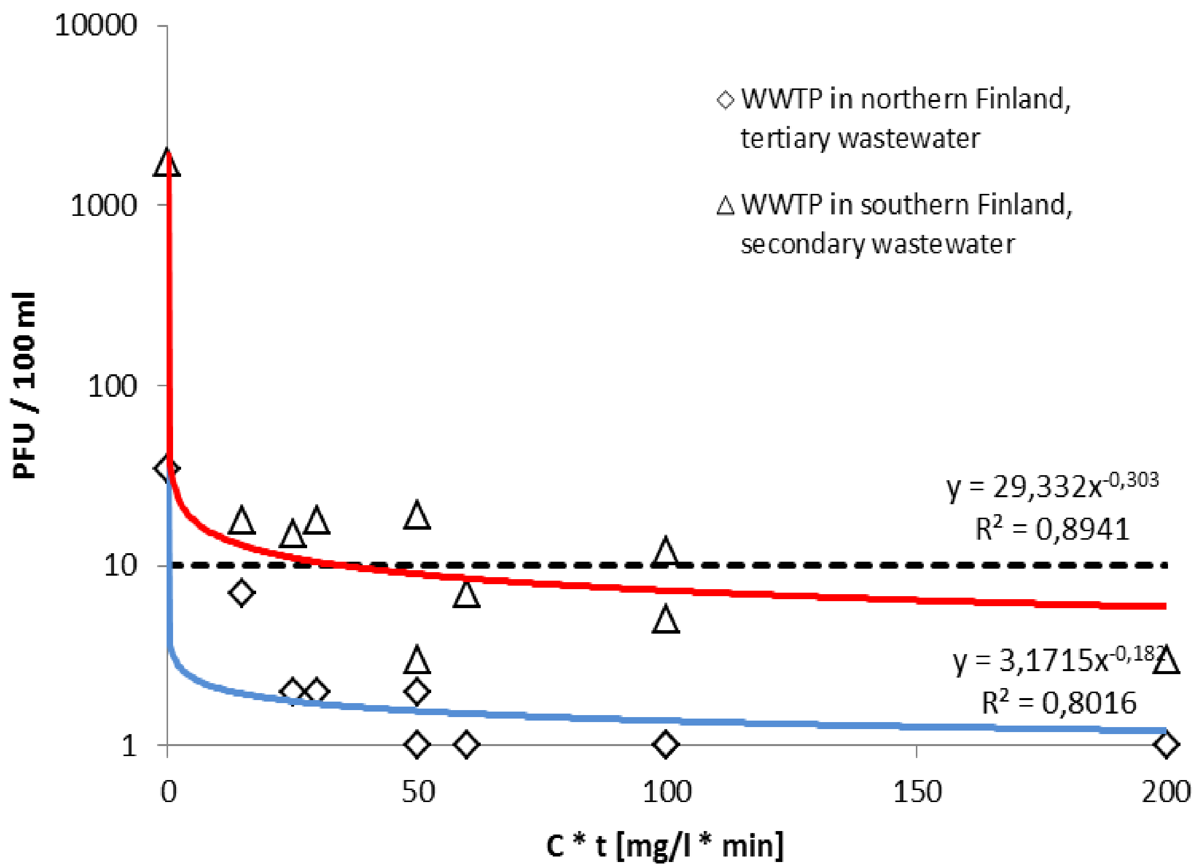


Figure 2 – Male ($F^+$) specific coliphage virus amount at different C· t values of PAA. There are results from two WWTPs in Finland. One is using tertiary filtration and the other sedimentation as a final unit process.

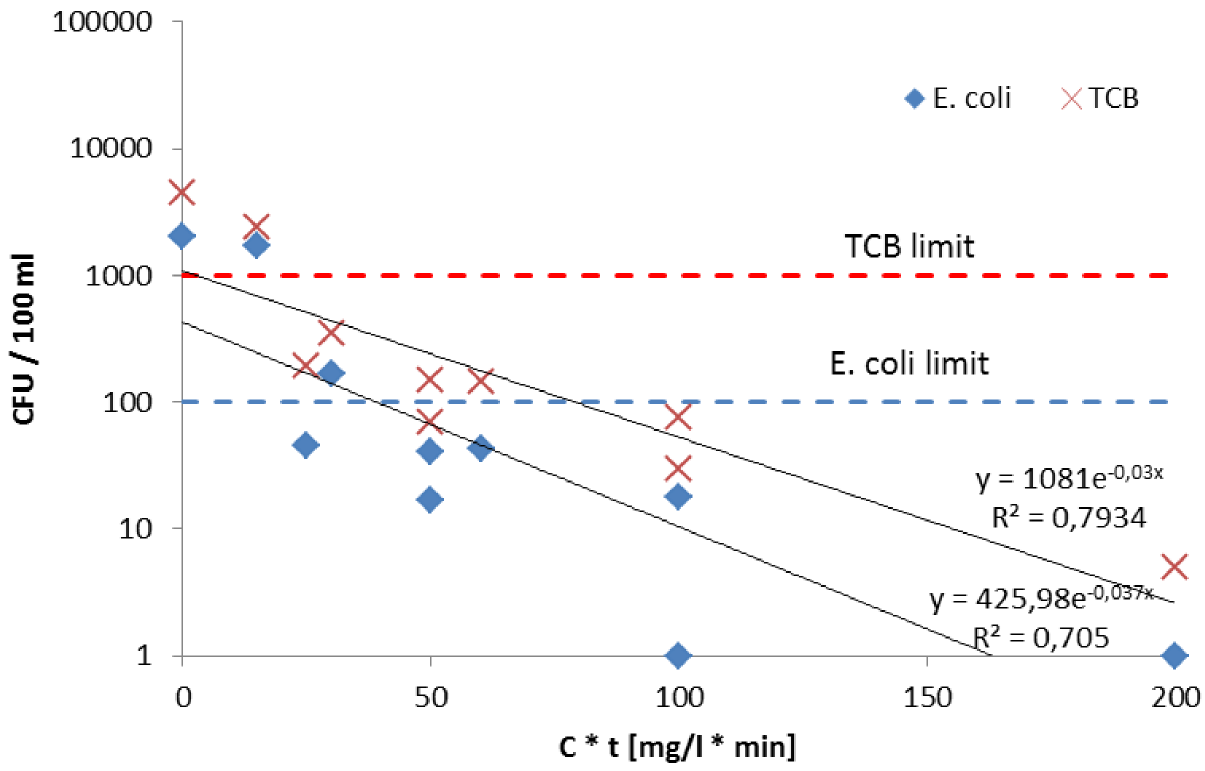


Figure 3 – *E. coli* and TCB results from a Russian WWTP

## Выводы

Перуксусная кислота (PAA) обладает такой же эффективностью, как и хлор, при обеззараживании сточных вод после вторичной и третичной очистки.

Сточные воды после обеззараживания PAA соответствуют российским и европейским нормативам для прибрежных вод.

Сравнение экономических показателей (суммы инвестиционных и эксплуатационных затрат) различных методов обеззараживания для очистных сооружений различной производительности свидетельствует о , рентабельности применения перуксусной кислоты по мере удорожания электроэнергии.

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## WASTEWATER DISINFECTION WITH PERACETIC ACID: BACKGROUND INFORMATION AND EXPERIMENTAL RESULTS

*Tero Luukkonen*

PAC-Solution Ltd, Pasilankatu 2,
FI-00240 Helsinki, Finland

Nowadays there is a great choice of methods of waste water treatment. Physical and chemical methods such as chlorine (gaseous or hypochlorite), chlorine dioxide, ozonation and UV disinfection are widely used. Despite that applying methods are quite efficient against pathogens, there are still some disadvantages. Peracetic acid (PAA) is a quite new method of waste water treatment. The article presents the comparison of the new and current methods. Carried out in Finland results of investigations on waste water after tertiary treatments are shown, comparison of currently applied sodium hypochlorite dose and Peracetic acid is presented. Data on pilot testing at waste water treatment plants of Russia and Finland which helped to clarify the efficiency of the treatment process with use of RAA as a disinfectant is presented.

**Key words:** waste water, disinfection, disinfectants, peracetic acid

## ОБЕЗЗАРАЖИВАНИЕ ОЧИЩЕННОЙ СТОЧНОЙ ВОДЫ ПЕРУКСУСНОЙ КИСЛОТОЙ

*Теро Луукканен*

PAC-Solution Ltd, Pasilankatu 2,
FI-00240 Helsinki, Finland

В настоящее время существует большой выбор различных способов обеззараживания сточной воды. Широко используются физические и химические методы, включая хлор (газообразный или гипохлорит), двуокись хлора, озонирование и ультрафиолетовое облучение

(УФО). Несмотря на то, что применяемые методы достаточно эффективны против патогенов, все они имеют некоторые недостатки. Перуксусная кислота (PAA) достаточно новый метод обеззараживания сточной воды. В статье приводится сравнение нового метода с существующими. Показаны результаты испытаний в Финляндии на сточной воде после третичной очистки и представлено сравнение дозы применяемого гипохлорита натрия и перуксусной кислоты. Приведены данные по опытным испытаниям на очистных сооружениях России и Финляндии, позволившие уточнить эффективность процесса обеззараживания с применением PAA в качестве дезинфектанта. Получены зависимости по количеству кишечных палочек и общих колиформных бактерий, а также ($F^+$) специфических колифагов при различном значении произведения концентрации PAA на время его действия. Обобщены результаты испытаний на очистных станциях в Финляндии (третичная очистка) и в России (вторичное осаждение).

**Ключевые слова:** сточные воды, обеззараживание, дезинфектанты, перуксусная кислота

## ЗНЕЗАРАЖЕННЯ ОЧИЩЕНОЇ СТІЧНОЇ ВОДИ ПЕРОЦТОВОЮ КИСЛОТОЮ

*Теро Луукканен*

Pac-solution Ltd, Pasilankatu 2,

FI-00240 Helsinki, Finland

Сьогодні існує великий вибір різних способів знезараження стічної води. Широко використовуються фізичні і хімічні методи, включаючи хлор (газоподібний або гіпохлорит), двоокис хлору, озонування і ультрафіолетове опромінення (УФО). Незважаючи на те, що ці методи досить ефективні проти патогенів, усі вони мають деякі недоліки. Пероцтова кислота (PAA) досить новий метод знезараження стічної води. У статті приводиться порівняння нового методу з існуючими. Показані результати випробувань у Фінляндії на стічній воді після третинного очищення і представлено порівняння дози гіпохлориту натрію і пероцтової кислоти. Наведені дані по дослідним випробуванням на очисних спорудах Росії і Фінляндії, що дозволило уточнити ефективність процесу знезараження із застосуванням PAA в якості дезинфектанту. Отримані залежності щодо кількості кишкових паличок і загальних коліформних бактерій, а також ($F^+$) специфічних коліфагів при різному значенні добутку концентрації PAA на час дії. Узагальнені результати випробувань на очисних станціях у Фінляндії (третинне очищення) і в Росії (вторинне осадження).

**Ключові слова:** стічні води, знезараження, дезинфектанти, пероцтова кислота

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