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INVESTIGATION OF HOUSEHOLD LAUNDRY WATER AS AN ALTERNATIVE WATER SOURCE

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Abstract

The goal of our research is to study the potential treatment options for the relatively contaminated greywater fraction from washing, in order to use this fraction as an alternative water source. During the research to compare the purification efficiency of different greywater treatment solutions we have created a constant composition synthetic laundry greywater, based on tap water, which represents the real laundry water in the terms of quality. As greywater treatment solutions, in terms of physical pre-treatment procedure we used a sand filtering method, and in terms of chemical processes we used coagulation and oxidation. Based on treatment efficiencies, we can say that the treatment procedures can achieve significant quality improvements, but none of the methods can achieve the required cleaning efficiency by itself. In order to reach the optimum quality parameters, the use of combined methods is required.

Keywords: *greywater, laundry water, reuse, sustainability.*

1. Introduction

Water is a basic need for every living organism in order to survive. The gap between needed, and available water resources, increases day by day. Nowadays we have to pay significant attention to sustainable water management, which makes waste water and household greywater recycling more and more important. By collecting and treating these waters, we can obtain a treated water that can be recycled at household level, for activities that do not require tap water quality, such as toilet flushing, irrigation or even for car washing.

2. About greywater

Greywater is the waste water from dish-washing, bathing and laundry, which excludes the water used for toilet flushing. The greywater fraction - laundry water - which is specifically investigated in our research, contains high concentrations of surfactants or detergent, bleaches and fibres from clothing, as well as dead human epithelial cells and hairs **[1]**. In addition to the presence of detergents in greywaters, we must expect an increase in the micro- and macro-element content of the water, since relatively high concentrations of trace elements and heavy metals are present in the waste waters produced by households, which in the case of reuse can pose significant pressures on the ecosystem.

2.1. Detergents

During the washing process detergents are used to remove contaminants. This means that greywater contains a large amount of surfactant that can be discharged into the surface water by household waste water, where it forms a thin layer of foam on the surface, reducing the amount of oxygen that can be absorbed by the water. It also reduces the efficiency of the self-cleaning process, which can lead to the onset of algal blooms. In order to avoid this, it is important to clean the greywater fraction of these surfactants and other contaminants, before reusing **[2]**.

3. Treatment methods

We can use several treatment methods for obtaining treated greywater, these can be: physical, chemical, physio-chemical and biological processes.

Filtration and sedimentation are the main operational solutions of physical processes. Filtration is usually not sufficient on its own, so it is also used as a pre-treatment method. Its goal is the removal of suspended solids and other particles from the used water **[3]**.

Coagulation is the main operational solution of chemical methods **[4]**. Coagulation refers to the destabilization of colloidal particles as a result of the reduction or elimination of the repulsive force between the particles. The destabilization of the particles can be accomplished, for example, by coagulant compounds. Most commonly iron salts, and aluminium salts are used, which produces micro-flocs. These flocs bind to colloidal particles smaller than a given size, filter them out and clear them from the aqueous phase. This floating material can be easily separated from the aqueous phase in the sedimentation and in the flotation tanks **[5]**.

The chemical treatment process may also be an oxidative solution which results in the decomposition of organic contaminants, and due to its disinfectant effect, can reduce toxicity and degrade colour and odours **[6]**.

There are only international regulations which are available on the quality of treated greywater. These directives highlight two of the qualification parameters, as follows: biological oxygen demand (BOD_5) at 10 mg/l concentration and turbidity at 2 NTU value is suggested to be maximized as a condition for reuse **[7]**.

4. Synthetic greywater

During the research to compare the purification efficiency of different greywater treatment solutions we have created a constant composition synthetic laundry greywater, based on tap water, which represents the real laundry water in the terms of quality. The composition of real samples is highly variable, so constant water composition is required to monitor correct treatment efficiencies, and this can be synthetically developed according to a given formula, and provided for further testing. In the production of synthetic laundry water, the quality parameters were established in previous research by the Department of Environmental Engineering **[8]**. The components of the samples were different detergents and fabric softener and to represent the contaminations vegetable oil and nutrient broth were also used. During the preparation of the synthetic laundry water, the changes of the water parameters characterizing the composition of the sample were systematically followed, with the addition of a component. As a qualifying step, water quality parameters of the samples were examined in parallel measurements, such as: pH, turbidity, electrical conductivity (EC), biological oxygen demand values (BOD), dissolved organic carbon (DOC) content and zeta potential values.

5. Study of treatment methods

We studied the mechanical treatment of filtration efficiency in the first stage. During the filtration process, a quartz sand filter was used. Analysis of the measured parameters is shown in **Table 1.** which illustrates that the filtration caused a decrease in pH values due to precipitated and filtered detergents. As a result of the treatment, the amount of biodegradable organic matter, the content of dissolved organic matter, as well as the value of turbidity were significantly reduced.

Table 1. *Water quality parameters of the filtrated sample*

		Synthetic water	Filtration
pH	-	7.87-8.16	7.66-7.68
EC	mS/cm	1.18-1.28	1.02-1.27
Zeta-potential	mV	-37.2-(-28.3)	-30-(-22.1)
Turbidity	NTU	97.76-175.05	43.88-133.04
DOC	mg/l	283.2-514.55	107.09-144.05
BOD_5	mg/l	360-666.67	183.67-235

Subsequently, chemical treatment procedures were investigated. Iron(III)-chloride was used as a coagulant during the coagulation process, which was added to the water sample in various concentrations as a solution. The change in zeta potential was continuously measured, and from these results, the appropriate amount of chemical was determined to achieve the optimum zeta potential values of 0±5 mV. The corresponding zeta potential values were achieved by adding a minimum of 46, but maximum of 60 mg/l $FeCl_3$. The efficiency of the treatment is illustrated in **Table 2.**

Table 2. *Water quality parameters of the optimal $FeCl_3$ dose-treated sample*

		Synthetic water	Coagulation
pH	-	7.87-8.16	2.99-3.95
EC	mS/cm	1.18-1.28	1.45-2.17
Zeta-potential	mV	-37.2-(-28.3)	-4.45-4.22
Turbidity	NTU	97.76-175.05	392.31-504.31
DOC	mg/l	283.2-514.55	139.85-154.45

Compared to the characteristics of the initial synthetic laundry water, the pH is shifted to a quite acidic range due to the presence of coagulant ($FeCl_3$). Specific electrical conductivity and turbidity have increased due to flocculated particles. The purpose of the treatment is to remove organic contaminants, which can be monitored by measuring the total organic carbon content (DOC). After treatment, this value was decreased by almost 60 % compared to the initial values.

Oxidation, another chemical procedure, was used during the research to remove organic pollutants from the greywater samples. During the oxidation, different amounts of hydrogen peroxide (H_2O_2) were added to the sample as an oxidizing agent. The treatment resulted in an increase in pH and a slight decrease in turbidity, conductivity and in DOC values.

6. Conclusions

Based on treatment efficiencies, we can say that the treatment procedures can achieve significant quality improvements, but none of the methods can achieve the required cleaning efficiency by itself. On its own, oxidation did not significantly change the quality parameters of the synthetic laundry water samples either.

The efficiency of applied processes was monitored by measuring various water quality parameters, these are as follows: pH, turbidity, electrical conductivity, zeta potential. In addition, the biological oxygen demand and dissolved organic carbon content of the samples were analysed for quantification of organic matter content.

The percentages of treatment efficiencies are shown in Table 3. which illustrates the magnitude of changes in the untreated sample's quality parameters.

Table 3. *Analysis of treatment efficiencies*

	Filtration	Coagulation	Oxidation
pH	5.31% decrease	57.33% decrease	2.93% increase
EC	7.44% decrease	43.6% increase	10.32% decrease
Zeta-potential	27% decrease	99.5% decrease	9.31% decrease
Turbidity	50% decrease	242.9% increase	30.59% decrease
BOD_5	56.7 % decrease	-	-
DOC	64.4 % decrease	59.15% decrease	20.35% decrease

According to the data in Table 3, it can be concluded that sand filtering shows an improvement in all water quality parameters, the decrease was mainly in the amount of organic matter content, while in case of turbidity values ~50% improvement was achieved. During coagulation, treatment with the optimum dose of coagulant results in a zeta potential value of close to 0 mV, which means that the efficiency was very good and the total organic carbon content could be reduced by almost 60% with this method. However, due to the presence of coagulant ($FeCl_3$), the pH was significantly shifted in the acidic condition and the turbidity value was very high due to the formation of flocs.

There was an increase in pH with oxidative treatment, but the other parameters show a slight decrease, which means there was an improvement in quality.

Based on this, it can be concluded that all three treatment processes can achieve quality improvement, but neither of them was capable on its own of achieving sufficient purification efficiency demanded by international recommendations. In order to reach the optimum quality parameters, the use of combined methods is required. Our final goal is to effectively combine treatment steps and produce effectively treated laundry water that can be used at a household level, for example for toilet flushing or irrigation.

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