University of Applied Sciences Upper Austria

FH – Wels

Analysis and reduction of wastewater loads of a paper plant for the production of medical and hygiene products

Fachprojekt

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Abstract

A high amount of water is needed for several processes regarding the production of pulp and paper. Traditionally the pulp and paper industry is an eco-friendly one with inherently only low and slightly harmful emissions. Nonetheless the production process causes wastewater loads of organic carbon compounds, which have to be treated.

The company Paul Hartmann GmbH in Grimmenstein runs a pulp factory which produces pulp for medical and hygiene products. The wastewater is physically and mechanically pretreated and afterwards discharged into the municipal wastewater treatment plant Grimmenstein-Edlitz-Thomasberg. The wastewater loads occasionally occur to be too high (peak loads), which causes severe problems in the receiving municipal wastewater treatment plant.

In terms of content the emphasis of this paper is on the analysis of the correlation of the Paul Hartmann GmbH's effluent wastewater loads in comparison with the wastewater loads of the municipal wastewater treatment plant Grimmenstein-Edlitz-Thomasberg including their causes and consequences, such as peak loads. Furthermore it provides an overview of the current state of the art wastewater treatment methods at pulp and paper plants and also an exposition of the effects on the municipal sewage plant.

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1 INTRODUCTION

1.1 Description of the Company

Originally at the site in Grimmenstein a wood mill was operated and after temporarily having manufactured cardboard, the production of pulp and paper was started in 1935. In 1971 the company was taken over by the Montana group, which was incorporated by PAUL HARTMANN GES.M.B.H. Austria in 1986.

The PAUL HARTMANN AG is an internationally active company in the field of medical and hygiene products with nearly 10.000 employees. Its main business areas are wound treatment, incontinence hygiene, surgical risk protection and disinfection. The company's headquarters is located in Heidenheim/Brenz Germany.

The PAUL HARTMANN GES.M.B.H. is a subsidiary of the HARTMANN GROUP. It currently employs more than 130 people and operates two locations, Wiener Neudorf (administration) and Grimmenstein (production).

At the site in Grimmenstein high-quality pulp products for wound care, incontinence hygiene, and for commercial and industrial application are produced. (Hartmann, Umwelterklärung 2013)

Figure 1: Plant in Grimmenstein

1.2 Description of the plant

The plant has a total area of 4 hectares and includes the production area for the production and processing of pulp, an administration building, a depot for finished products and raw materials, a workshop for repair and maintenance work as well as a laboratory for acceptance sampling and a boiler to generate steam. Also there is a hydroelectric power plant with a maximum production of 600 MWh/a, which is powered by a nearby canal. A wastewater treatment system consisting of flotation and sedimentation is also available.

Among other things the product range includes recycling incontinence sheets, pulp products, industrial crepe and plaster crepe made from 100% recycled paper, paper towel rolls, cotton products, raw material for paper towels, various tissue papers, and cellulose swabs. The main raw materials used are paper and purchased pulp.

Water is used for the following purposes at the site in Grimmenstein:

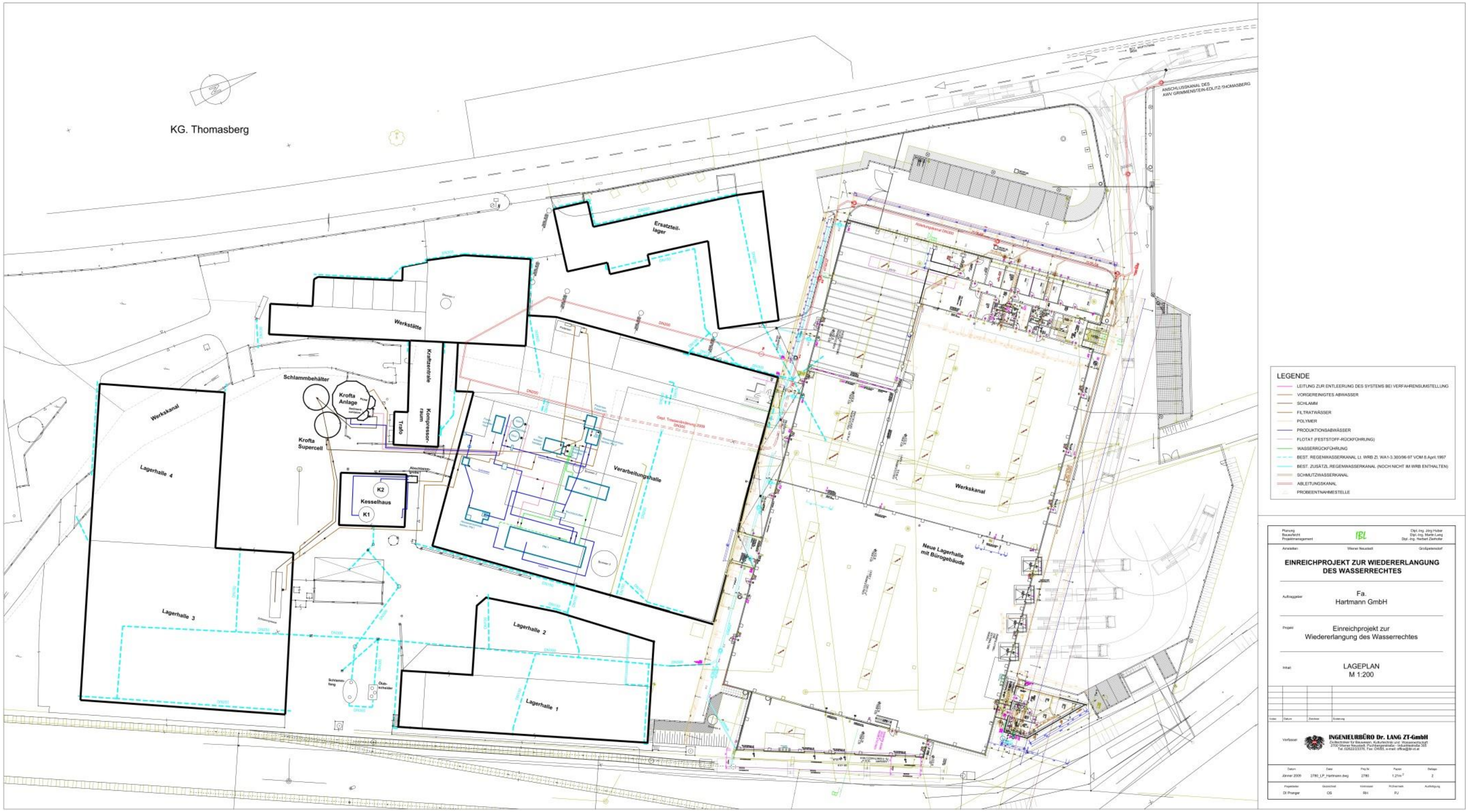
- for paper making
- to generate steam
- as wash water in the cleaning of the paper machine
- in sanitation

The required fresh water for the production is provided by the plant's own water well, whereas the water that is needed for sanitary purposes is taken from the local supply network. In order to conserve fresh water resources, around 50% of the water is being recycled.

The amount of recycled water is dependent on the nature of the various products and can therefore vary. Due to the evaporation in the paper machine and the drying machine, the wastewater rates are about 8% lower than the water consumption.

The wastewater is mechanically and physically pretreated and then dispensed to the local sewage plant AVW Grimmenstein-Edlitz-Thomasberg. The terms and conditions are specified in the assessment NKW2-WA-0496/002. Because of the different hygiene requirements and thus different production program, fluctuations result in the parameters of the wastewater. (Hartmann, Umwelterklärung 2013)

Figure 2: Site plan



2 SITUATION OF WATER AND WASTEWATER IN GERMANY

In 2010 the water and wastewater situation in the German pulp and paper industry was determined by the Verband Deutscher Papierfabriken e.V. and the Papiertechnische Stiftung, by carrying out a comprehensive survey. It was attended by 92 companies which collectively produce 77% of the amount of paper, cardboard and pulp manufactured in Germany. The evaluated data should serve as a benchmark to improve and optimize the processes and plants.

Among other things this information demonstrates that the wastewater treatment in the pulp and paper mills is to 90% fully biological and carried out at an internal or a municipal sewage plant. These plants generate 96% of the reported production volume. Less than 1% of this production volume is produced in plants which discharge their wastewater directly with chemical-mechanical, but without biological treatment.

Almost 60% of the companies that treat their wastewater fully biologically within the company, operate with aerobic processes while 40% also operate with an upstream anaerobic stage. Aerobic processes are primarily the traditional aeration tanks, but also moving bed reactors (MBBR), biofilters and trickling filters are used as aerobic high loaded systems.

In the anaerobic processes IC reactors (Internal Circulation reactors) are currently the most widely used technology. The remaining market share is split by Biobed® and USAB reactors (upflow anaerobic sludge blanket) and reactors operating after contact sludge processes.

The most frequent problems occur at the compliance of threshold values because of too high wastewater temperatures and high COD values in the effluent. Almost a quarter of the plants that participate in the survey have problems with one of these limits. (Jung, Kappen, Hesse, & Götz , 2011)

Thus, the biological purification of wastewater in the pulp and paper industry in Germany is the standard on the basis of the requirement to use the best available technology (Best Available Technique BAT, IVU Directive [EG(2008)]) and wastewater treatment in accordance with the state of the art methods (§ 57 WHG). It is expected that they will be supplemented by more advanced processes. (MÖBIUS, 2010).

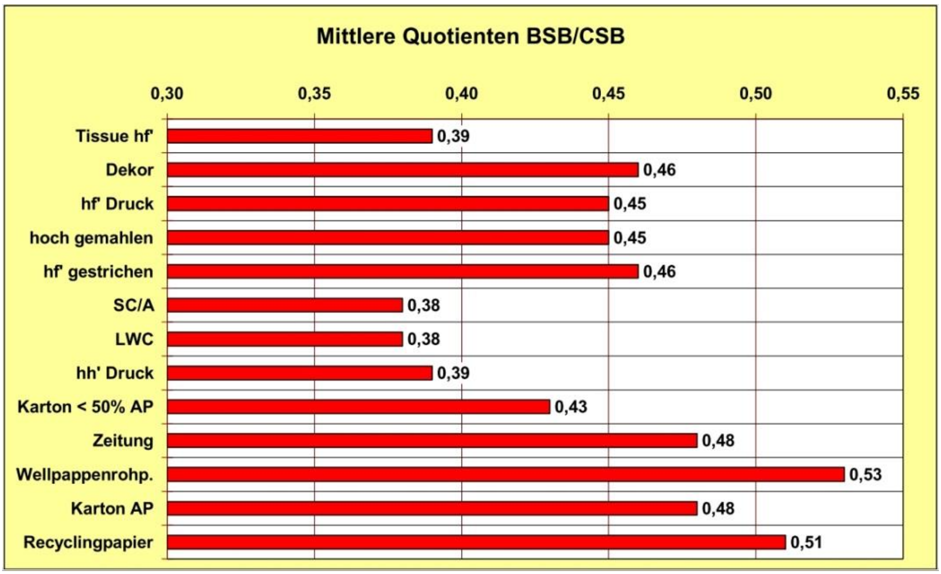
3 BIOLOGICAL WASTEWATER TREATMENT

For the wastewater treatment it has to be considered that the production of pulp and paper is fundamentally different in their process engineering as well as in type and amount of produced wastewater. Biological processes have a key position in the pulp and paper industry as they are less costly than physical-chemical processes. In addition, the required low BOD effluent concentrations can usually only be achieved by biological methods. Because of the one sided composition of the wastewater and the poor nutrient content of the wastewater, in any biological treatment systems nutrients (N and P) and in rare cases even trace elements have to be added.

Wastewaters are monitored for their pollutional strength on the basis of their oxygen demand. There are two widely used measures of oxygen demand. The chemical oxygen demand (COD) test determines the organic content in terms of both biodegradable and non-biodegradable compounds, whereas the biochemical oxygen demand (BOD_5) test evaluates the biodegradable fraction of the wastewaters. Although the BOD_5 test is not specific to any pollutant, it continues to be one of the important general indicators of the potential of a substance for environmental pollution of surface waters.

The biodegradability of pulp and paper mill effluents depends on the BOD_5/COD ratio. Biochemical processes can only lead to the elimination of BOD_5, but if a certain amount of BOD is removed a corresponding amount of COD also is eliminated. The largest proportion of biodegradable material in pulp and paper mill effluents are carbohydrates. They have a ratio of 0.60 to 0.65 of the total COD and are equivalent to the easily degradable part. Substances that are difficult to degrade have a much lower BOD_5/COD ratio, are usually not degraded at all or hardly degraded and their COD remains after biological treatment as residual COD. The mean ratios of different, relevant wastewaters of the paper and pulp production are shown in figure 3. (MÖBIUS, 2010)

Figure 3: Mean ratios of BOD/COD



However, the BOD_5/COD ratio is also dependent on the bacteria used. Ideally this would be a ratio of 1.0. Some poorly degradable substances can only be degraded with particular bacterial strains. In a study of the Institute of Genomics and Integrative Biology in India specific bacterial strains were isolated and tested for their ability to reduce organic loads from paper mill effluent. To compare the biodegradability bacterial strains from ordinary wastewater were used with a mixture of strains of Micrococcus, Staphylococcus, Kurthia zopfii, Alcaligenes faecalis and Pseudomonas aeruginosa. Thereby BOD_5/COD ratios of 0.65 to 0.67 could be obtained while the ratio of the conventional non-specific bacterial strains only reached 0.37 to 0.40. Thus, the biodegradability may be enhanced with specific strains of bacteria. (KUMAR & DHALL, 2010)

Ozone treatment of paper mill effluent can increase its biodegradability, as toxic compounds are degraded and changes in molecular weight fractions are encouraged. The Department of Chemical Engineering of the Complutense University of Madrid has examined various methods based on oxidation processes in combination with biological processes (MBR). It has been shown that an efficient wastewater treatment method depends essentially on the composition of the paper mill effluent. With a consumption of 2.4 g O_3/L 60% COD reduction was achieved at the wastewater treatment of a Kraft pulp mill. For the treatment of the wastewater of a paper mill which uses recycled paper as raw material, the COD could only be reduced by 35%. (MERAYO, 2013)

In a study of the Department of Biological and Environmental Science at the University of Jyväskylä in Finland different methods of pretreatment of secondary sludge from waste water of paper and pulp mills were tested to improve the thermophilic anaerobic digestion and compared. This involved hydrothermal, enzymatic, chemical, and ultrasonic methods that have been studied individually or in combination. The highest increase in methane yield (36%) was reached with hydrothermally pre-treated secondary sludge (150 °C, 10 min). The soluble COD fraction could be increased by more than nine fold. (BAYR, KAPARAJU, & RINTALA, 2013)

3.1 Anaerobic wastewater treatment

The anaerobic wastewater treatment is widely used in the pulp and paper industry and is regarded as the standard. It has many potential advantages in comparison to aerobic treatment such as lower sludge production, lower chemical consumption, smaller land requirements due to smaller reactors and energy production in the form of methane. The majority of the eliminated carbon is converted into biogas. Problems in the anaerobic wastewater treatment often arise from the fact that biomass is susceptible to changes in environmental conditions and has very low growth rates. Based on current information, the treatment with full BOD reduction to <20 mg/L is not possible. Therefore anaerobically treated wastewater must always also be treated aerobically before it can be discharged in a body of water. In general, the application of the method is recommended, if the COD is >2 g/L is.

Not all types of wastewater are suitable for anaerobic treatment and the choice of the treatment process depends greatly on the composition of the wastewater. At high sulfate concentrations in reducing conditions sulfide is formed. This sulfide formation leads to inhibition of the methanogens or even has toxic effects, so methanogens are displaced. Also the preferred reproduction of sulfate-reducing microorganisms has a detrimental effect and the amount of methane formed is considerably reduced. The ratio of reducible COD to reducible sulfur is crucial for the inhibition. When this ratio is less than 100 it is very probable that problems can occur. An anaerobic treatment is not reasonable if the ratio of reducible COD to reducible sulfur is less than 15.

Anaerobic wastewater treatment can be reliable and efficient if the composition of the wastewater is suitable and treatment processes are appropriate. Compared to activated sludge treatment plants the maintenance of technically well-equipped anaerobic systems is lower.

Typical results of anaerobic digestion of paper mill effluents are efficiencies of η_{COD} = 70 % and η_{BOD} = 80 %. Higher efficiencies can be achieved under favorable circumstances, but this is not always economical. About 0.4 Nm^3 of biogas per kg eliminated COD are produced. The typical composition is 70-80% methane, 20-30% CO_2, <5% H_2S and traces of other gases.

For the selection of the most appropriate process, the following three requirements are crucial:

- Containment or recirculation of the biomass in the reactor under exclusion of air
- It is necessary to ensure a sufficient transfer area between biomass and waste and a rapid removal of the reaction products
- The undisturbed symbiosis of acetogenic and methanogenic microorganisms is required

For the treatment of wastewater from the paper industry processes in the mesophilic temperature range (35-38 °C) are predominantly used. The pH values in the range of 6.8 to 7.2.

For the treatment of papermill wastewater, two systems are mainly used, suspend growth systems and fixed bed systems. (MÖBIUS, 2010)

1.1.1. Systems using suspended biomass

Systems using suspended biomass are contact processes or upflow process. The upflow-anaerobic-sludge-blanket-process (UASB) has found wide application in this area. This process is based on the formation of microorganism pellets of about 1 to 3 mm in diameter which have a high sedimentation velocity, so biomass can be well retained in the reactor. At the top of the reactor, a three-phase separation for biogas, water and sludge is situated.

Further developments of the UASB process use internal and external circulations and come up with lower hydraulic residence times than conventional methods.

They are also known as the EGSB (Expanded Granular Sludge Bed) method. (MÖBIUS, 2010)

The paper mill Roermond in the Netherlands used a UASB reactor plant since the start in 1983 until the end of 2000, which was extended by a second UASB reactor in 1992. The operation was largely trouble-free at an initial average loading rate of 10 kg COD/m^{3}d, which was doubled later. In January 2001, the UASB reactor was replaced by an IC reactor which could achieve reduction values of 70% for COD and 80% for BOD_5. (MÖBIUS, 2010) CHEN and HORAN report COD and sulphate removal rates of 66% and 73% using an UASB reactor with a hydraulic retention time of 6 h. (CHEN & HORAN, 1998)

1.1.2. Fixed bed processes

In these processes the microorganisms grow as a thin layer on the carrier material. The fixed-film reactor has structured plastic elements as biomass carrier.

In recent years it has rarely been used, but is intensely considered in research and could have good prospects for a renaissance.

Anaerobic filter with a bed of granular carrier material is less suitable because it is prone to blockage in the presence of undissolved substances in the wastewater from paper mill effluents. Fluidized-bed processes are better suited, but are also technologically complex and place great demands on technology. (MÖBIUS, 2010)

PEREZ et al. have compared an anaerobic filter system with corrugated plastic bodies and a fluidized bed reactor within laboratory facilities. Removal rates of 81% respectively 50% of the organic loads could be determined. (PEREZ , ROMERO , & SALES, 1998)

1.1.3. Combined processes

The combination processes join the advantages of both types of processes of anaerobic treatment. A hybrid reactor is passed from the bottom to the top and in its lower part suspended or pellet sludge is maintained in suspension by the hydraulic inflow. The upper part of the reactor is filled with clog-free plastic elements. Separate feedback loops can set optimum flow rates for each of the lower or upper part of the reactor. Biomass accumulates on the carrier and provides an additional biomass inventory. The attached biomass contributes both to the removal of biodegradable organic substances and to the production of a suspended biomass with improved settling characteristics.

In Canada hybrid reactors are used for the treatment of pulp wastewater, but it has not prevailed against the EGSB (Expanded Granular Sludge Bed) process. (MÖBIUS, 2010)

3.2 Aerobic wastewater treatment

The aerobic treatment occurs almost exclusively by bacteria and fungi that build up biomass out of organic matter and nutrients (N and P) under consumption of oxygen. As a by-product carbon dioxide is formed. Optimum growth conditions for the micro-organisms are in the mesophilic temperature range at 25 - 35 °C and at a pH between 6.5 and 8.5.

1.1.4. Activated sludge process

The activated sludge process is the most widely used biochemical application and has been used to treat nearly every type of wastewater. It also is the most cost effective solution, if the wastewater which should be treated is in a suitable condition and is often applied in two-stage systems as the second stage. As a one-stage process the activated sludge process is not safe for operation, because the formation of bulking and floating sludge can cause severe problems in operation. By eliminating the easily degradable carbohydrates and other interfering components of the wastewater (e.g. organic acids) in an upstream stage, the second downstream stage is much more reliable. Therefore the activated sludge treatment is preferably combined with other techniques (such as anaerobic treatment + activated sludge treatment, trickling filter + activated sludge treatment).

During aerobic degradation of wastewater compounds, surplus of biomass is produced. Nutrients (N and P) are required for proper operation and biomass growth, which are usually not present in pulp and paper mill effluent and hence have to be added. For the separation of sludge and treated wastewater final sedimentation basins are required for sedimentation and separation of biomass.

Paper mill effluents include a particularly high portion of carbohydrates, enhancing the tendency to form bulking sludge. Since this is hard to handle in single-stage activated sludge plants, it is usually preceded by other biological methods. (MÖBIUS, 2010)

At G.B. Pant University of Agriculture and Technology in India, a study was carried out in order to investigate the sequential anaerobic aerobic treatment of paper mill effluents in a two-stage bioreactor with an addition of various fungi strains. With fungus Paecilomyces sp. the COD could be reduced by 93% and also colors (80%) AOX (74%), lignin (81%) and phenol (76%) could be reduced. (Singh, 2007)

1.1.5. The membrane-bioreactor

Membrane bioreactors (MBR) are based on an activated sludge treatment which is combined with effluent membrane filtration. The treated wastewater is separated as permeate while dissolved high molecular substances > 0.05 microns are retained by the membrane and recirculated. The membrane units for biomass separation can be designed differently. Cross-flow modules or submerged membranes are mostly used.

MBR processes have many advantages. Biomass can be maintained at much higher concentrations than in conventional activated sludge systems, since the membranes provide a complete retention of all microorganisms. Additionally the construction of a final sedimentation basin or a sludge separation stage is omitted.

The method is particularly suitable for internal use or recirculation of treated wastewater into the production. The application of the MBR method should however only be considered, if the benefits in the particular case justify the higher investment and operation costs. (MÖBIUS, 2010)

BERUBE and HALL were able to remove about 93% of the TOC with a membrane bioreactor. (BERUBE & HALL , 2000)

1.1.6. Trickling filters

Trickling filters with appropriate design and suitable biomass carrier material are reliable and need little maintenance. Companies, who produce paper and board out of recycling paper have to remove plastic particles and other impurities such als aluminium particles before pumping wastewater to trickling filters to avoid blocking of the filter material, since the cleaning of a clogged trickling filter is very cost intensive. The accumulation of biomass in the trickling filter has to be avoided as it leads to poor treatment performance and high odor emissions. Biomass layers should not exceed a thickness of more than 2 mm and can be performed by increasing the hydraulic load by recirculation of treated wastewater.

The maximum loads applied to trickling filters are high, because the risk of clogging and the feed concentration can be reduced by a corresponding high recirculation ratio. Volumetric loads up to 3 kg BOD_5/m^3*d can be applied with degradation rates of 50 to 60%. The maximum of the design load is usually at $L_V = 4$ kg/m^3*d. At higher loads the BOD_5 removal is significantly lower than 50%.

Because of the usually high recirculation ratio trickling filters provide a significant advantage of stability. Interfering effects of shock loads and variations in parameters such high or low pH values and high temperatures can be compensated. The excess sludge production and nutrient requirements are lower than for activated sludge treatment plants of medium load in trickling filters.

Nowadays trickling filters are continuously being replaced by high load moving bed reactors, for they can treat significantly higher volumetric loads with the same treatment performance. (MÖBIUS, 2010)

1.1.7. High-rate carrier biology

In the central European paper industry, high-load carrier biological wastewater treatment systems are applied with floating plastic working as biomass carrier in the MBBR system + activated sludge treatment. It should be considered that the carriers have to be moved in the reactor and that a sufficient air feed is required, which has to be significantly higher (oxygen concentrations in the MBBR of 3-4 mg/L) than it would be required for the biological degradation of carbonaceous substances. For the paper industry a sludge age below 10 d after high-load steps is sufficient to achieve an optimum COD removal.

In various paper mill effluents $\eta_{BOD5} > 50\%$ could be achieved at a volumetric load of up to 8 kg BOD_5/m^3*d. The operation of the reactors is simple and reliable, if the system conforms to the technological requirements. Calcium deposits on the biomass carriers can be avoided, if the nutrient supply is secured. (MÖBIUS, 2010)

1.1.8. Submerged fix-bed reactors

Biomass carriers (eg. activated sludge systems filled with trickling filter material), that operate predominantly or completely below the water surface, are designated as submerged fixed bed reactors.

In municipal wastewater treatment rotating contactors are often used. These contactors uses e.g. discs as carriers have a biological layer on their surface and are semi-immersed into the treatment tank. Oxygen supply is provided by contact of the biomass layer with air and also by entry into the water through rotation.

Such processes (Stählermatic) are only sporadically applied in the paper industry because activated sludge systems are more appropriate for high wastewater loads. The oxygen entry is provided exclusively by the rotation of the discs and therefore it is very limited. Due to lack of oxygen this systems may lead to considerable problems (odor emissions). (MÖBIUS, 2010)

1.1.9. Moving bed biofilm reactor

This process refers to moving bed biofilm reactors (MBBR), suspended carrier biofilm process or fluidized bed process and is a variation of biofilm system that works with floating biomass carriers. MBBR reactors are preferably used as high-load carrier biology in front of low-loaded activated sludge reactors, but can also be designed as low-load reactors with correspondingly higher treatment efficiency. When high efficiency is required two-stage reactors serve as a reasonable economical version.

The carrier material is retained by a grid inside the reactor. It can be used with about 1 to 4 cm length of plastic structures made of polyethylene or polypropylene. The BOD_5 elimination is determined with sufficient hydraulic residence time by the volumetric load and the type and amount of carrier material. (MÖBIUS, 2010)

ROVEL et al. could remove 76% BOD respectively and 62% COD with a biofilm reactor. (ROVEL , TRUDEL , LAVALLE , & SCHROETER , 1994)

1.1.10. Stabilization ponds

The efficiency of non-aerated sewage ponds after mechanical physical treatment is low for dissolved substances and inefficient in terms of space requirements.

Aerated lagoons can be used as an inexpensive alternative to other treatment methods, but only at low feed concentrations (<100 mg BOD_5/L) and a residence time of at least 3 days. (MÖBIUS, 2010)

3.3 Applied process combinations

For paper mill effluents in general both anaerobic and aerobic processes are suitable. The combination of both is usually the best solution, because thereby the advantages of both methods can be combined. The preferred process combination depends on the characteristics of the effluent, which should be treated. It is important to understand that most of the design considerations are site specific. The collection of samples from the wastewater to be treated, as well as performing lab analysis and onsite testing to determine the relevant parameters for process design is required.

Table 1: Processes dependent of the kind of wastewater to be treated

Production program	Preferred biological processes
Sulphate pulp	Aerated activated sludge cascade Moving bed reactor + activated sludge treatment
Sulphite pulp	Anaerobic reactor + activated sludge treatment
Wood-free paper BOD_5 < 70 mg/L: BOD_5 > 70 mg/L:	 Biofilter 2-stage biofilter, Activated sludge cascade
Coated papers	Activated sludge cascade Moving bed reactor + activated sludge treatment
Woodcontaining papers	Moving bed reactor + activated sludge treatment
Recycled papers	Anaerobic reactor + activated sludge treatment Moving bed reactor + activated sludge treatment

Activated sludge cascades are common for the treatment of wastewater from sulphate pulp production. An alternative is the combination of the fluidized bed reactor followed by activated sludge treatment.

For the treatment of wastewater from the production of sulphite pulp, anaerobic pre-treatment of easily biodegradable substances is often applied. The application of the cascade principle is advantageous, but not absolutely necessary. (MÖBIUS & HEBELE, 2001)

4 DESCRIPTION OF THE WASTEWATER TREATMENT OF THE PAUL HARTMANN GMBH

4.1 Physical-mechanical pretreatment of the wastewater

Two small single-cylinder paper machines produce cotton wool from artificial cotton and secondary raw materials. Afterwards in the "drying part" this cotton wool is processed into different products for hygiene, nursing and hospital supplies.

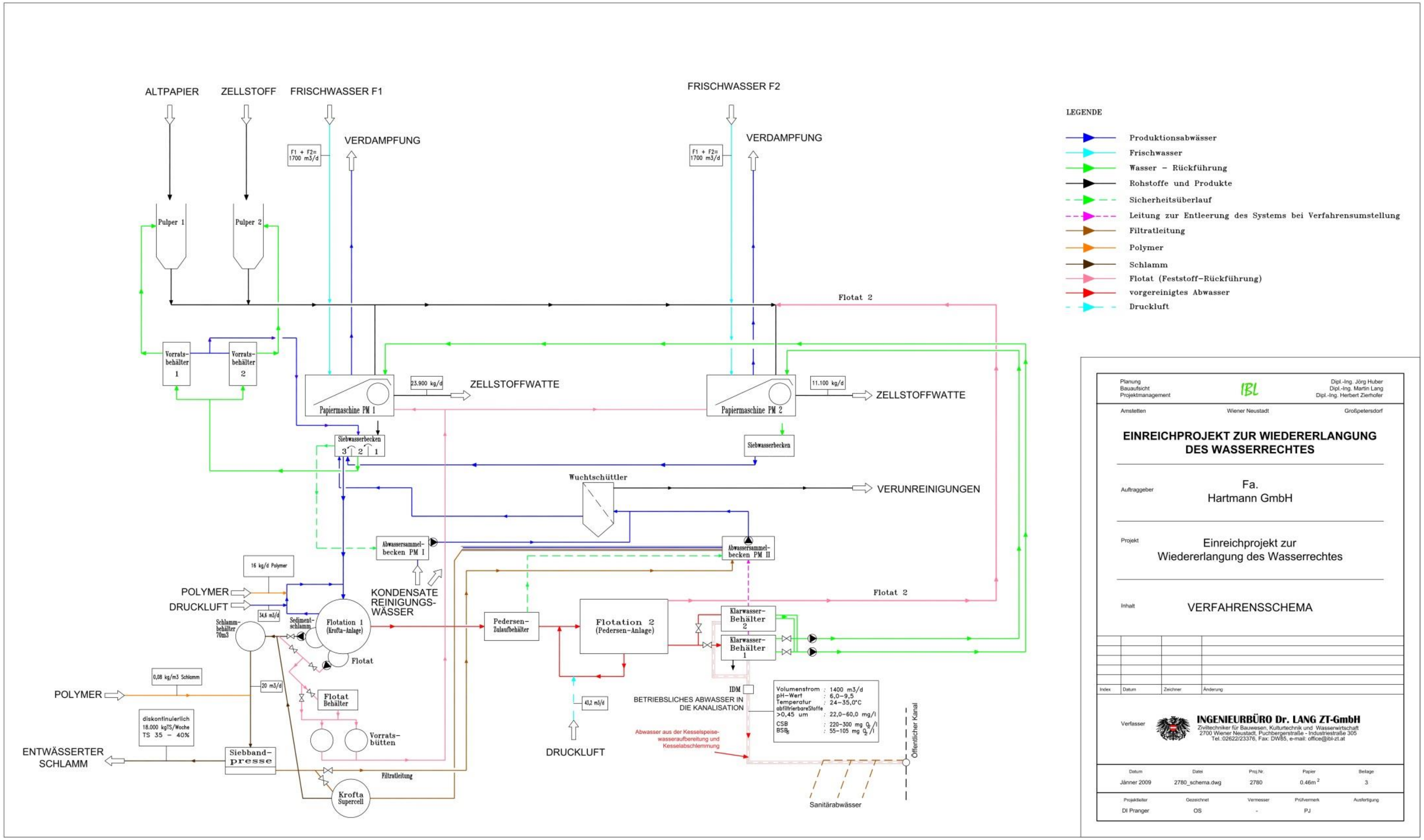
For the raw material sulphite pulp, sulphate pulp and recycled paper is used. Either 100% wood pulp or 100% recycled paper is used as raw material in the paper producing process.

First of all the raw material is mixed up in pulpers with water to form a substantially homogeneous fiber suspension. This is applied to the sheet formation on the sieves of the paper machine, mechanically dehydrated and dried on the heated surface of a "Yankee cylinder". The finished paper is subsequently removed from the system.

The process water discharged during this process is loaded with fibers, fiber fragments and other solid particles. It is mechanically sieved by fine filters and then transferred into an open circuit. In this cycle solids are separated by flotation and the produced flotation sludge is discharged. The treated wastewater and the remaining fiber sludge can be reused in the current production. Sediment sludge from the flotation units will be removed, dewatered and disposed of by an external provider.

Figure 4 shows the process flow diagram. In front of the flotation 1 (Krofta Sedifloat and Krofta Supercell plant) a mechanical treatment by screens is performed. The pretreated water of flotation 1 is then treated in a second downstream flotation 2 (Sven-Pedersen plant). (IBL Ingenieurbüro Dr. Lang, 2009)

Figure 4: Process flow diagram



5 PROBLEM

The production of paper for medical and hygienic purpose products is a very water-intensive industrial production process which creates a high level of wastewater. This wastewater is polluted with a high amount of dissolved COD and BOD_5 and has to be treated in order to avoid environmental impacts. The Paul Hartmann GmbH has the approval of the local wastewater association to discharge its wastewater via the sewer system to the sewage treatment plant of the AWV Grimmenstein-Edlitz-Thomasberg. Threshold values for the effluent (listed in table 2) according to assessment No. NKW2-WA-0496/002 have to be met. Due to different production programs with different raw materials (waste paper vs. pulp), variations of the wastewater parameters respectively increased wastewater loads can occur, which lead to transgressions of the threshold values. The exact causes of this increased loads need to be clarified and the wastewater loads should be reduced to the extent that the threshold values can be met.

Table 2: Threshold values

Parameters	threshold values acc. to assessment No. NKW2-WA-0496/002
Volume of wastewater [m^3/d]	1400
pH-value	6,5 - 9,5
Temperature [°C]	35
BOD_5 [kg/d]	150
COD [kg/d]	400

Furthermore it has to be determined whether and to what extent the municipal sewage plant is overloaded.

5.1 <u>Analysis of correlation of the wastewater loads</u>

The discharged wastewater from the Paul Hartmann GmbH forms a substantial part of the influent load of the sewage treatment plant of the AWV Grimmenstein-Edlitz-Thomasberg. It is assumed, that increasing influent loads of AWV sewage treatment plant are caused by the discharged wastewater of the Paul Hartmann GmbH.

To check if there is a correlation between the increasing loads of the AWV wastewater treatment plant and the self-monitored wastewater parameters of the Paul Hartmann GmbH, both values (influent to the municipal wastewater treatment plant and self-monitored parameters of the Paul Hartmann GmbH) were compared.

The data was evaluated and displayed as time series comparing the years of 2010-2012. For better illustration of the periodical fluctuations of the measured values, trendlines which show the moving average of a 14 day period were added and checked for correlations.

Furthermore the COD and BOD_5 influent loads were compared and analyzed by means of regression analysis. Since there are relatively few measurements of the sewage treatment plant, the 85% Percentile were also calculated to establish statistically corroborated design values.

1.1.11. Statistical analysis

Measured values of the wastewater effluent of the Paul Hartmann GmbH and the wastewater inflow to the sewage treatment plant of the AWV in Grimmenstein have been chosen to compare loads at dry weather conditions.
For the comparison of the pH-values, the measured values in the outlet of the Paul Hartmann GmbH and the maximum values of the pH value in the inlet of the sewage plant were used.
The person-equivalent specific loads (PE) and wastewater loads were calculated from the given data and compared as follows:

- Person-equivalent specific loads (PE):

$PE = \frac{BOD_5 * Q_{inflow}}{PE60} \quad PE = \frac{COD * Q_{inflow}}{PE120}$

- Loads:

$$BOD_5\left[\frac{kg}{d}\right] = BOD_5\left[\frac{mg}{L}\right] * Q_{inflow}[m^3] \qquad COD\left[\frac{kg}{d}\right] = COD\left[\frac{mg}{L}\right] * Q_{inflow}[m^3]$$

5.2 Comparison and interpretation of the time series

The measured data was given in separate tables from the Paul Hartmann GmbH and the sewage plant Grimmenstein. From this data diagrams for analysis and interpretation were created. It has to be considered, that there are often significantly less values from the sewage treatment plant available than from the Paul Hartmann GmbH. Therefore the trendlines of the sewage plant are not as informative as the trendlines calculated from the effluent values of the Paul Hartmann GmbH.

1.1.12. Wastewater flow

Figure 5 shows the 14-day mean values of the outflow of the Paul Hartmann GmbH (red) and the inflow of the sewage plant (blue) from 2012 which are represented as time series. In average about 30 to 40% of the wastewater flow into the sewage treatment plant are caused by the Paul Hartmann GmbH. The process of the in- and outflow volumes of the years 2011 and 2010 is shown in figure 6 and 7.

The threshold value specified in assessment No. NKW2-WA-0496/002 for the maximum wastewater flow from the Paul Hartmann GmbH is 1400 m^3/d. This limit was exceeded by approx. 164 m^3/d (mean value) at 69 days and hence in 19% of measurements in 2012. There are enough measurements of the wastewater flow are reliable.

Both curves for 2012 are almost parallel to each other, also the curves of the years 2011 and 2010 are similar, as can be seen in figure 6 and 7.

Figure 5: Wastewater volume 2012

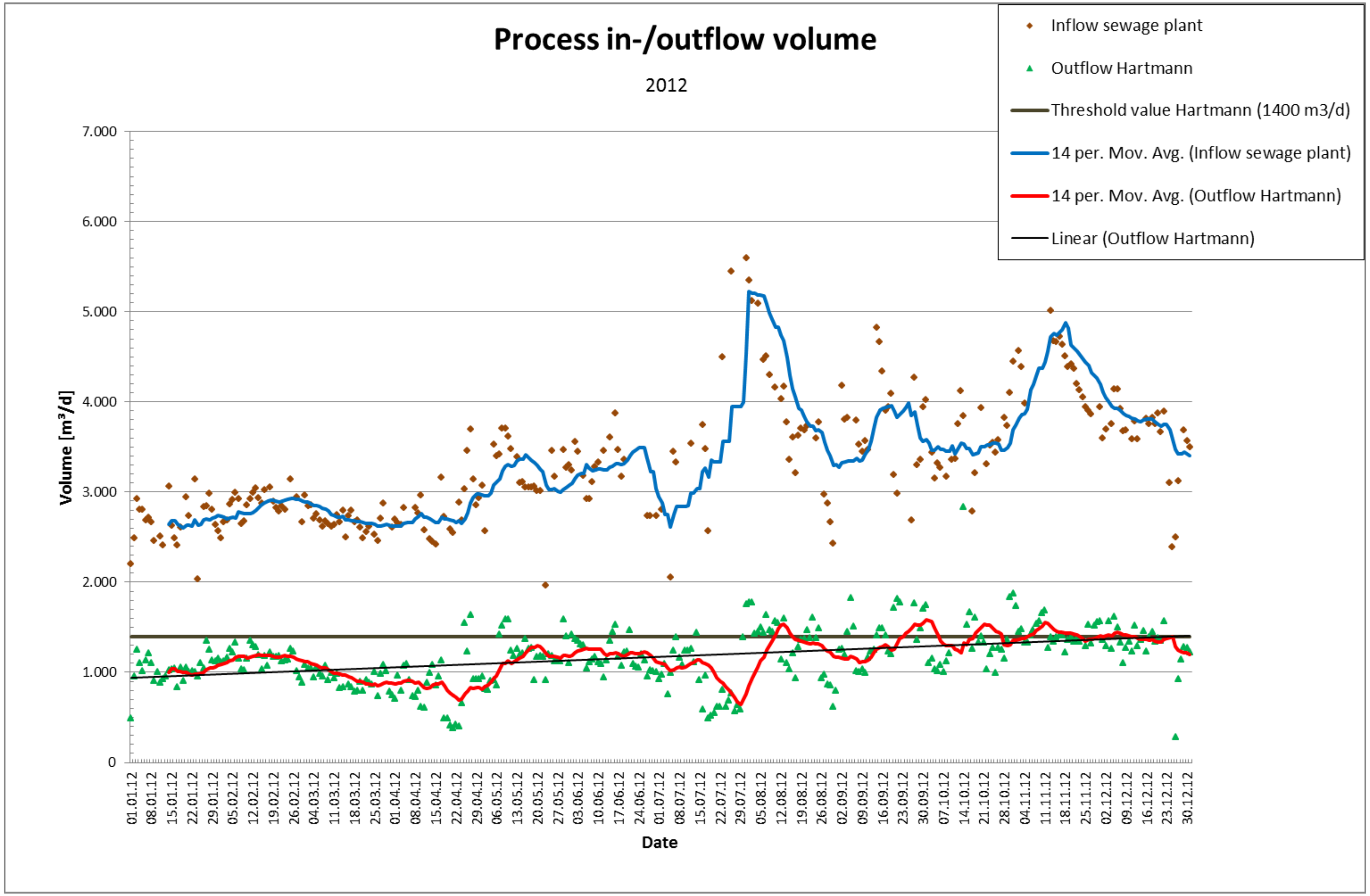


Figure 6: Wastewater volume 2011

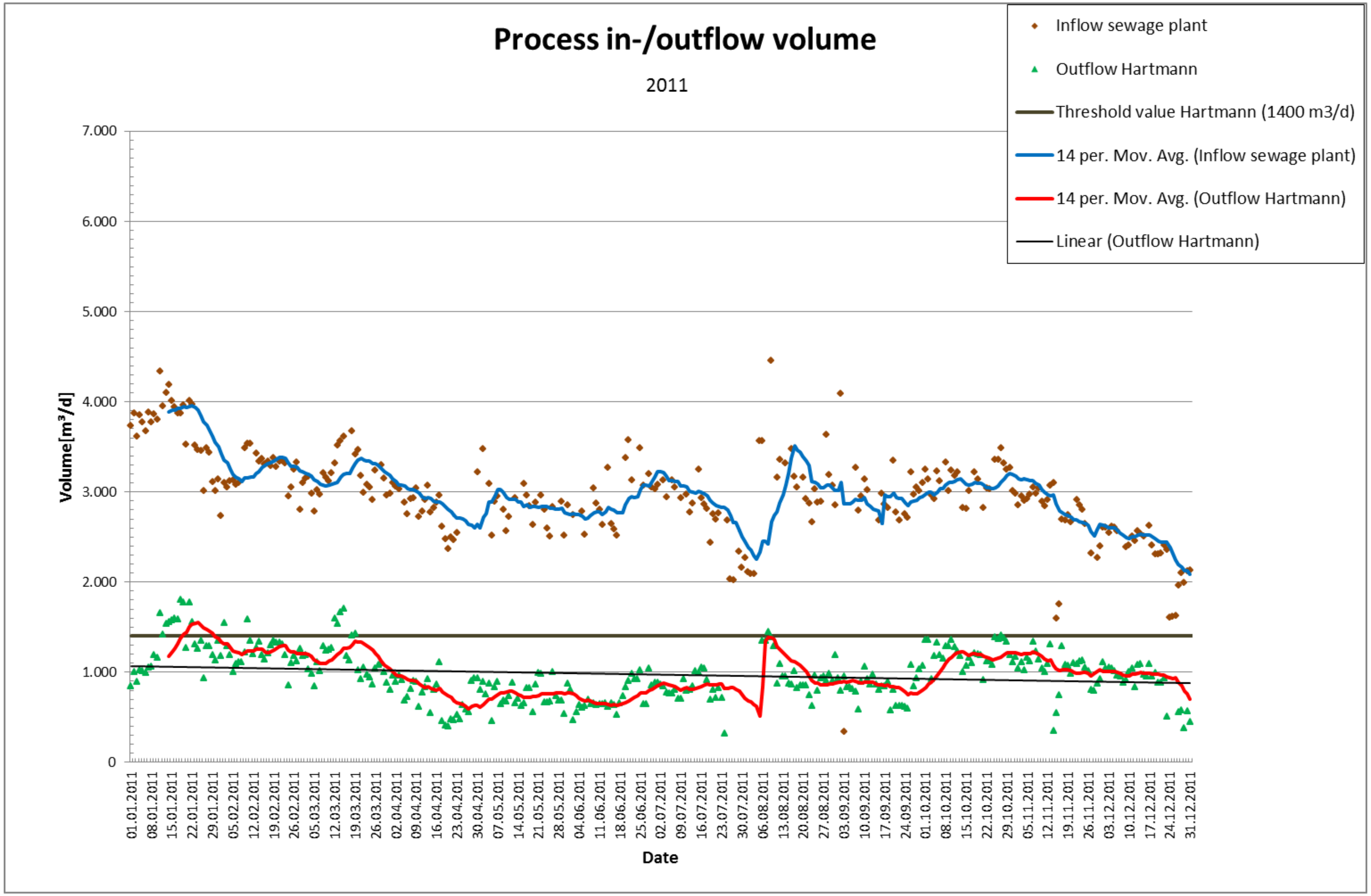
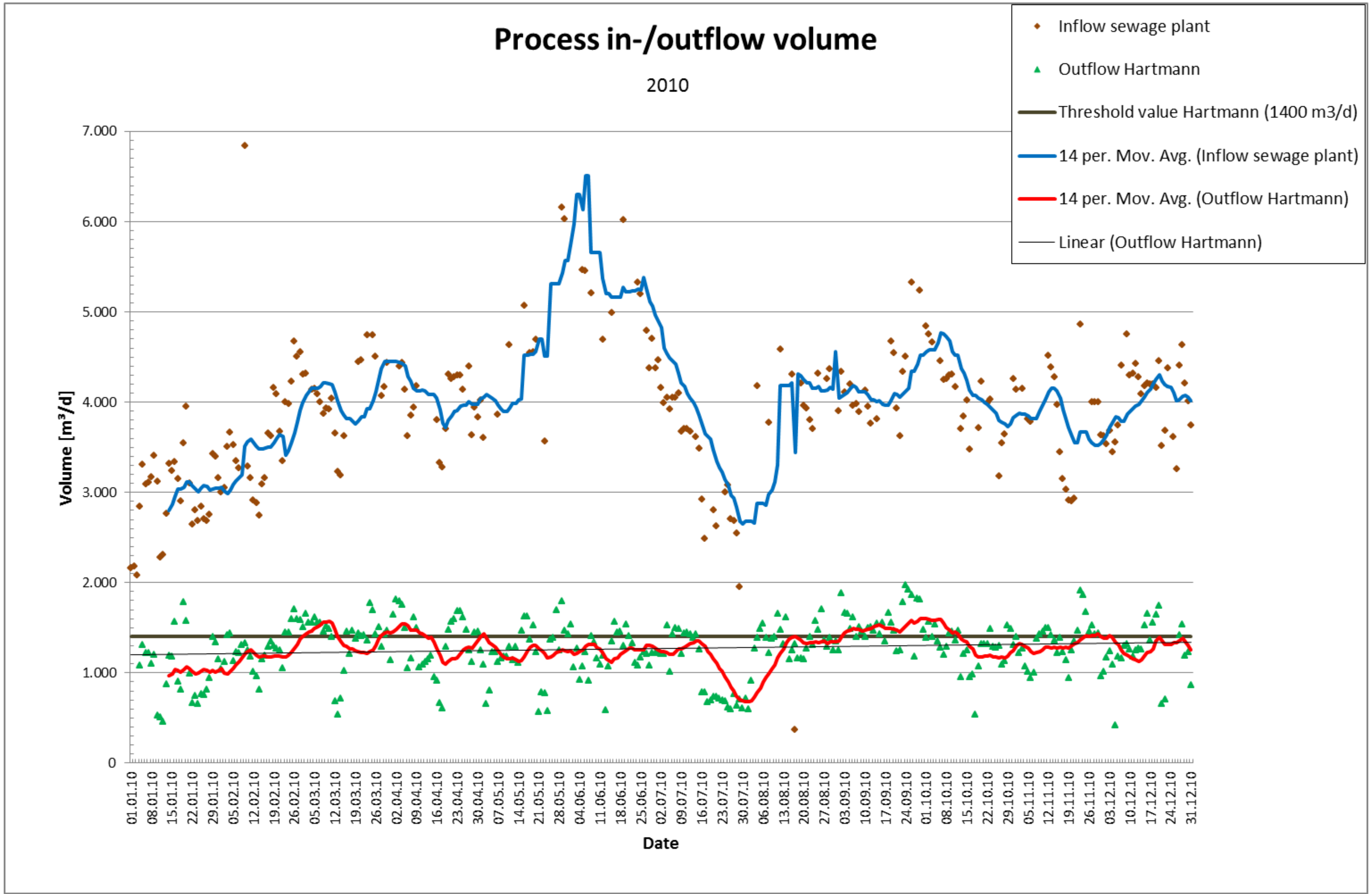


Figure 7: Wastewater volume 2010



5.2.1 pH – values

In figure 8 to 10 the pH values of the Paul Hartmann GmbH (red) and the process of the maximum pH values of the inflow to the sewage plant (blue) are shown.

The measured pH values in 2010 are characterized by slightly alkaline pH values in the effluent of the Paul Hartmann GmbH. The upper and lower limits of the pH values (according to assessment No. NKW2-WA-0496/002 is 6.5-9.5) never exceeds in the effluents of the Paul Hartmann GmbH. In the contrary periodically very low pH values could be determined in the inflow to the sewage treatment plant.

It should be also noted that the pH values of the Paul Hartmann GmbH hardly fluctuate. On the other hand, the pH values of the sewage treatment plant influent are highly fluctuating. This is important for the plant operation, because lower pH values in the influent indicate either an acidification of wastewater in the sewer system or measurement problems.

Low pH values as a result of acidification in the sewer system has to be considered critical, because on the one hand the concrete in the sewer system can be damaged due to corrosion, on the other hand organic acids in the influent may cause a higher risk of forming bulking sludge in the sewage plant.

Figure 8: pH - values 2012

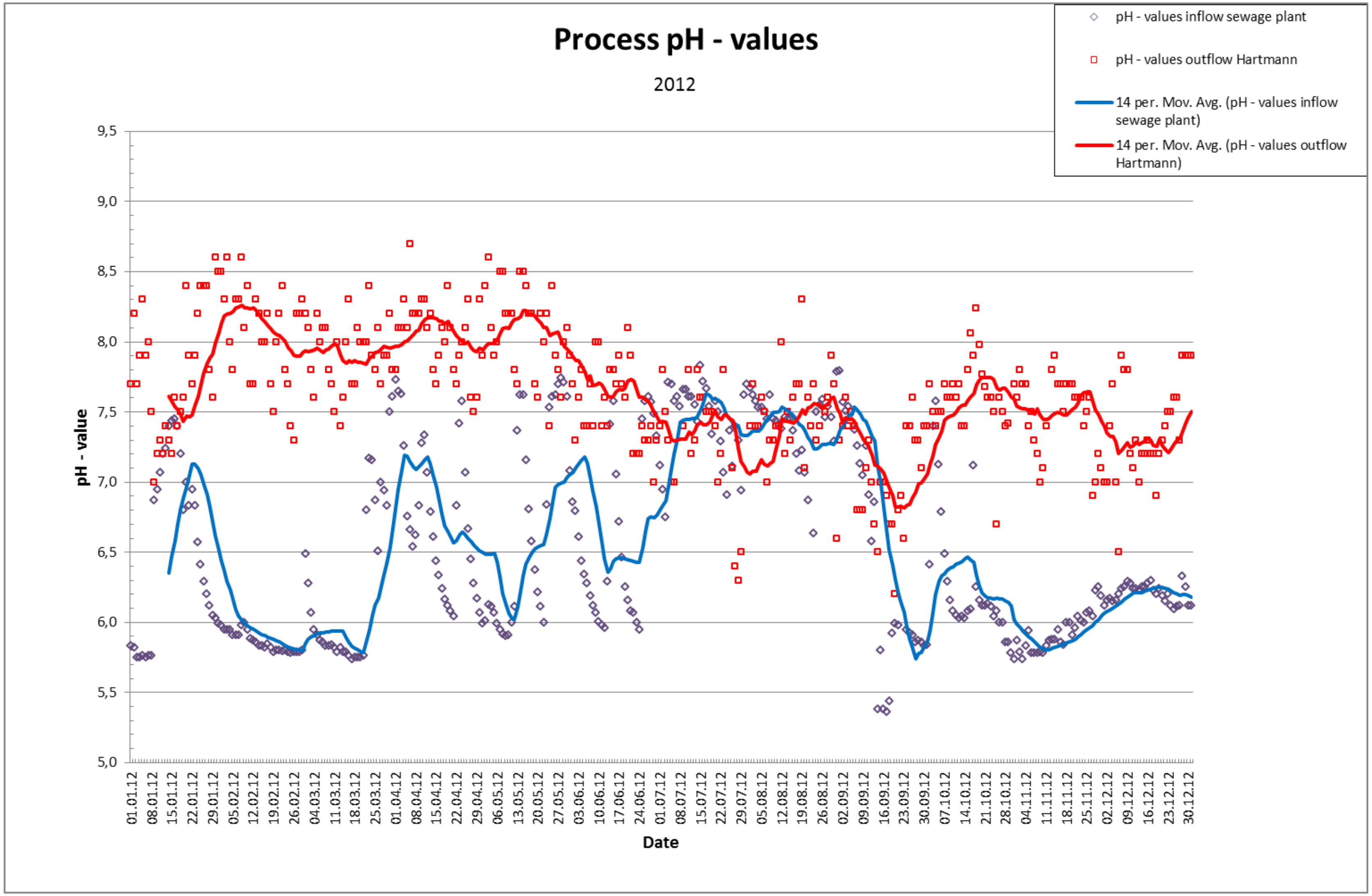


Figure 9: pH - values 2011

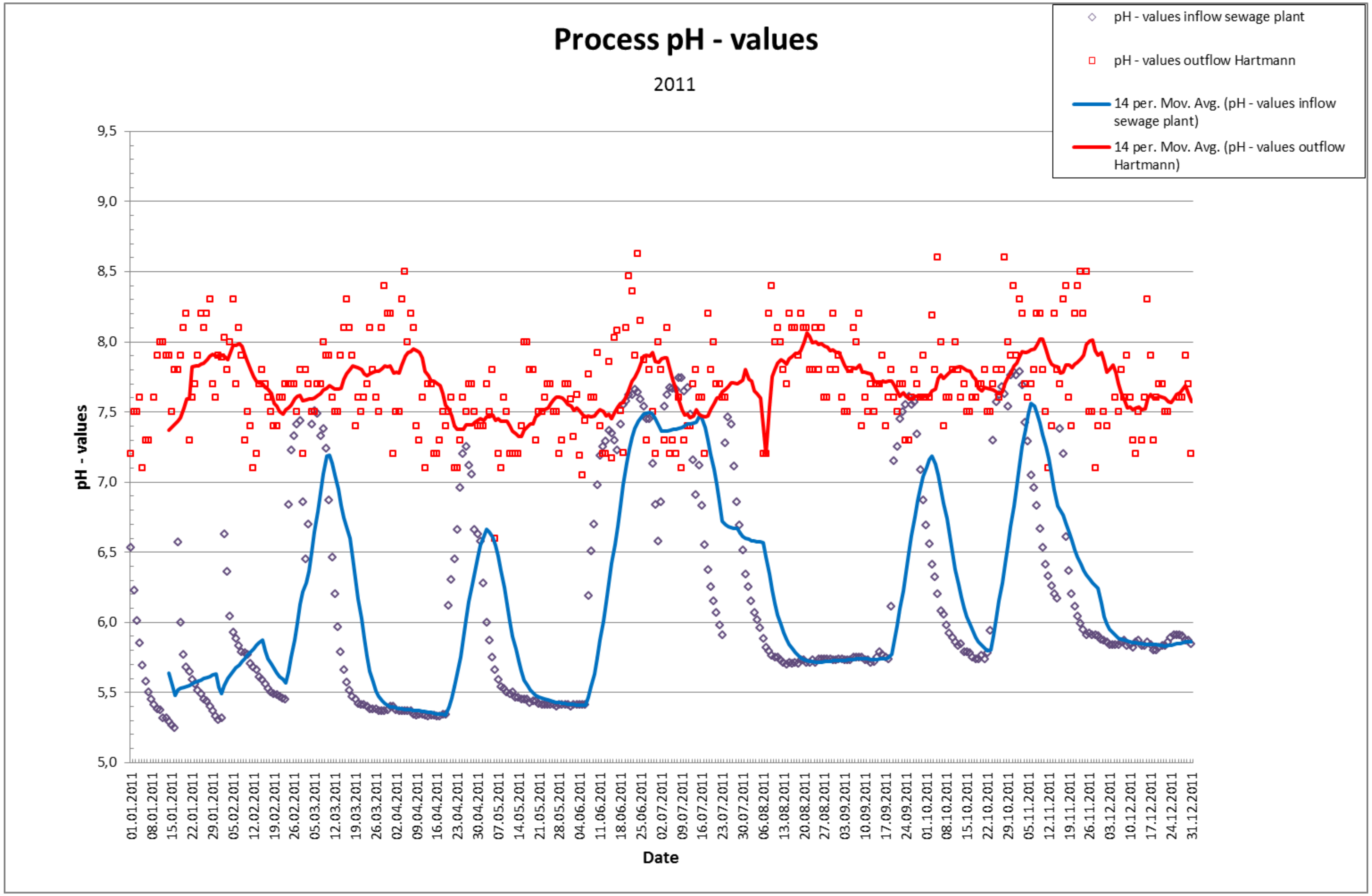
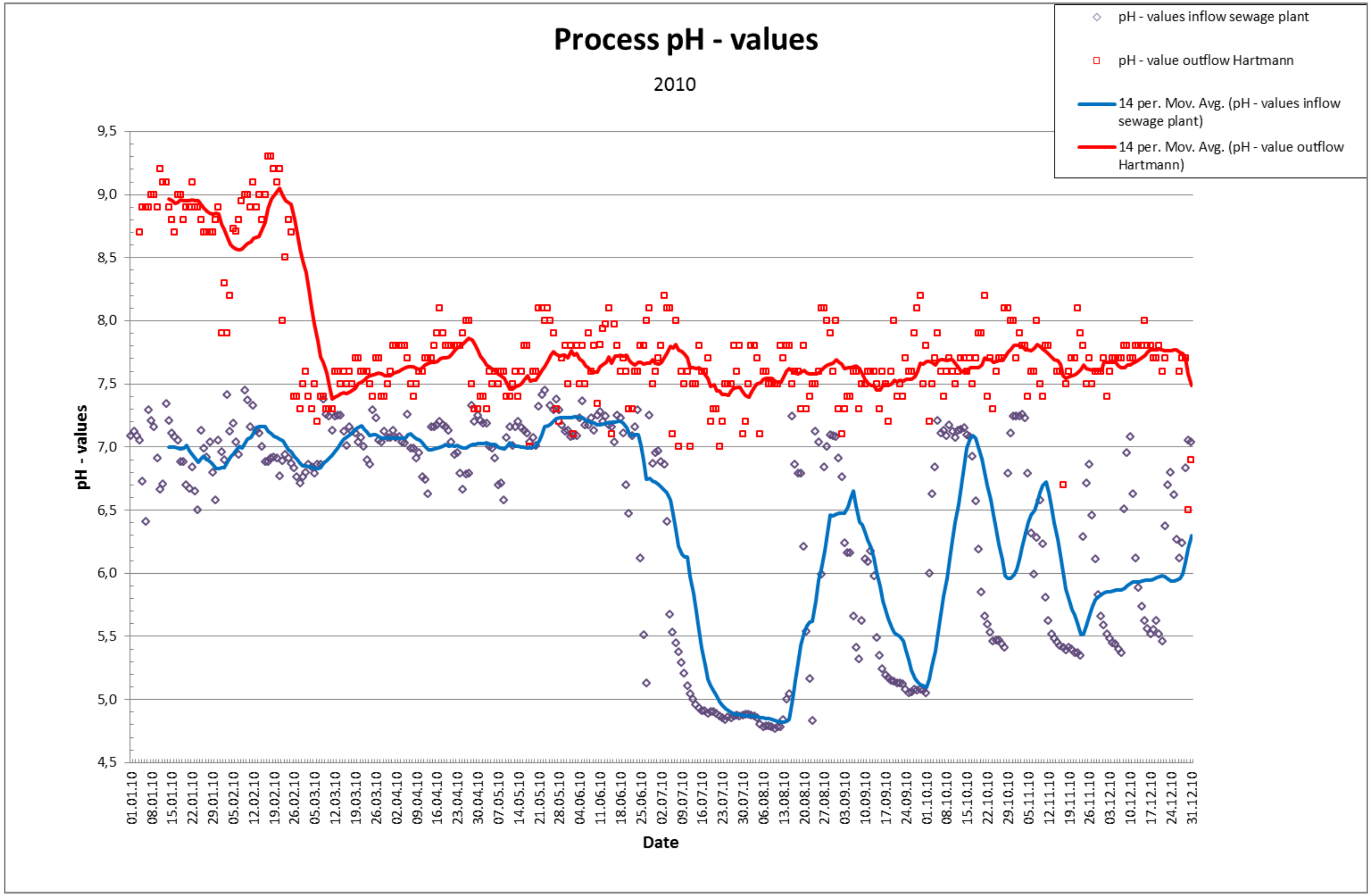


Figure 10: pH - values 2010



5.2.2 PE_{60}/BOD_5

In figure 11 to 13 you can see the outflow of the Paul Hartmann GmbH (red) and the inflow loads (blue) of the sewage treatment plant calculated as PE_{60}. As mentioned in Chapter 5.2 **there only few BOD_5 values analyzed in the inflow of the municipal sewage treatment plant, nevertheless it can be seen that the BOD_5 loads show an almost parallel tendency.**

According to assessment No. NKW2-WA-0496/002 the Paul Hartmann GmbH is allowed to discharge max. 150 kg BOD_5 acc. to 2.500 PE_{60} to the municipal sewage treatment plant. This limit was met in 2010, but in 2011 the limit exceeds by approx. 53 kg BOD_5/d. In 2012 the limit value of 150 kg BOD_5/d was exceed by approx. 93 kg BOD_5/d (see figure 14 – 16, mean value). The increase in BOD_5 loads (blue) in 2012 can be seen from the increasing linear trendline in figure 17.

The evaluation of the results from the inflow loads to the wastewater sewage treatment plant shows that measured values periodically exceed the threshold value of 12.230 PE_{60} (see also figure 5 -7), but the average values were approx. 9.750 PE_{60} and the 85 % Percentile was approx. 12.900 PE_{60}. According to this, the municipal sewage treatment plant has actually no reserves left. **This contradicts the existing assessment.**

Figure 11: PE_{60} values 2012

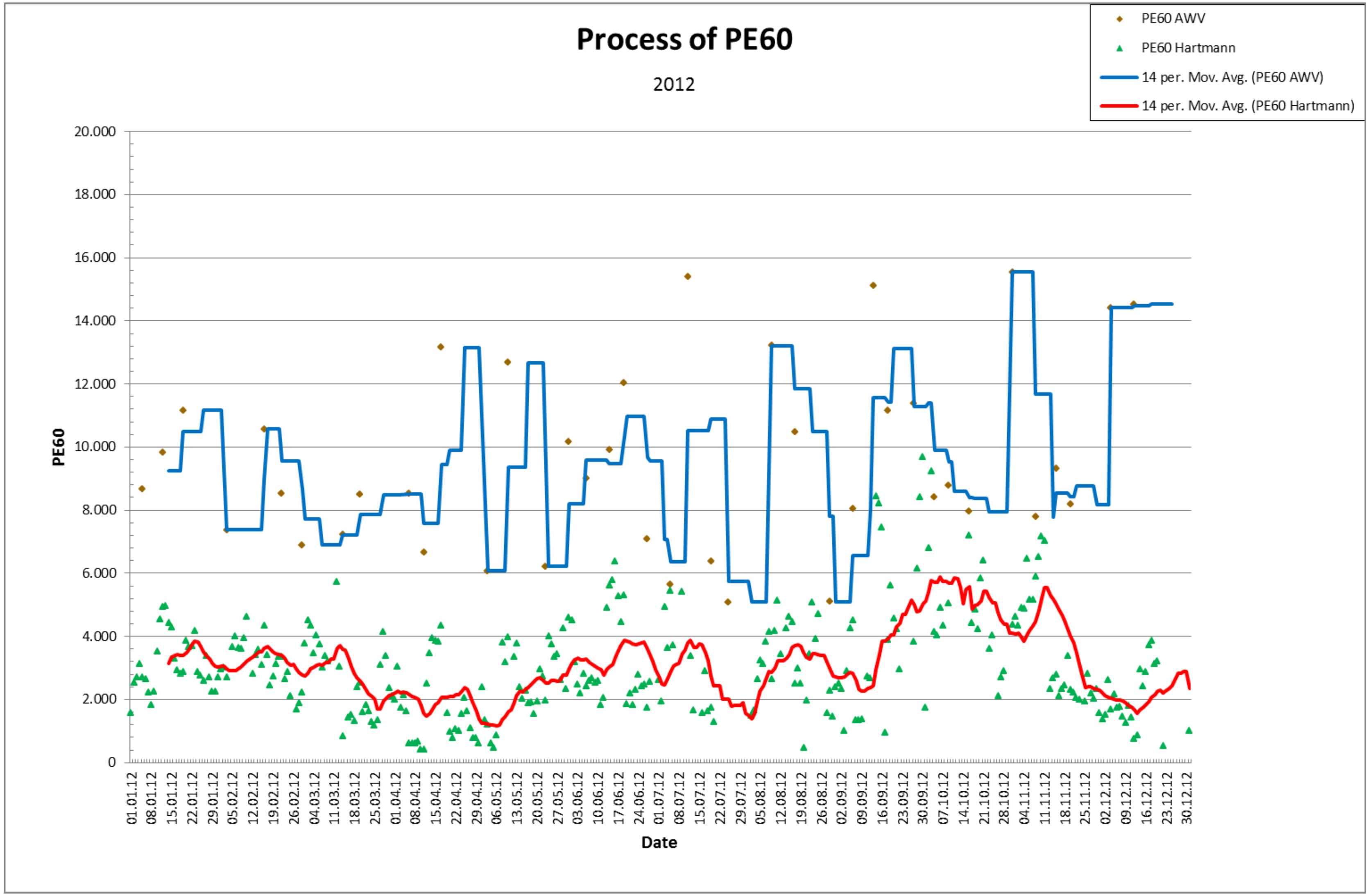


Figure 12: PE_{60} values 2011

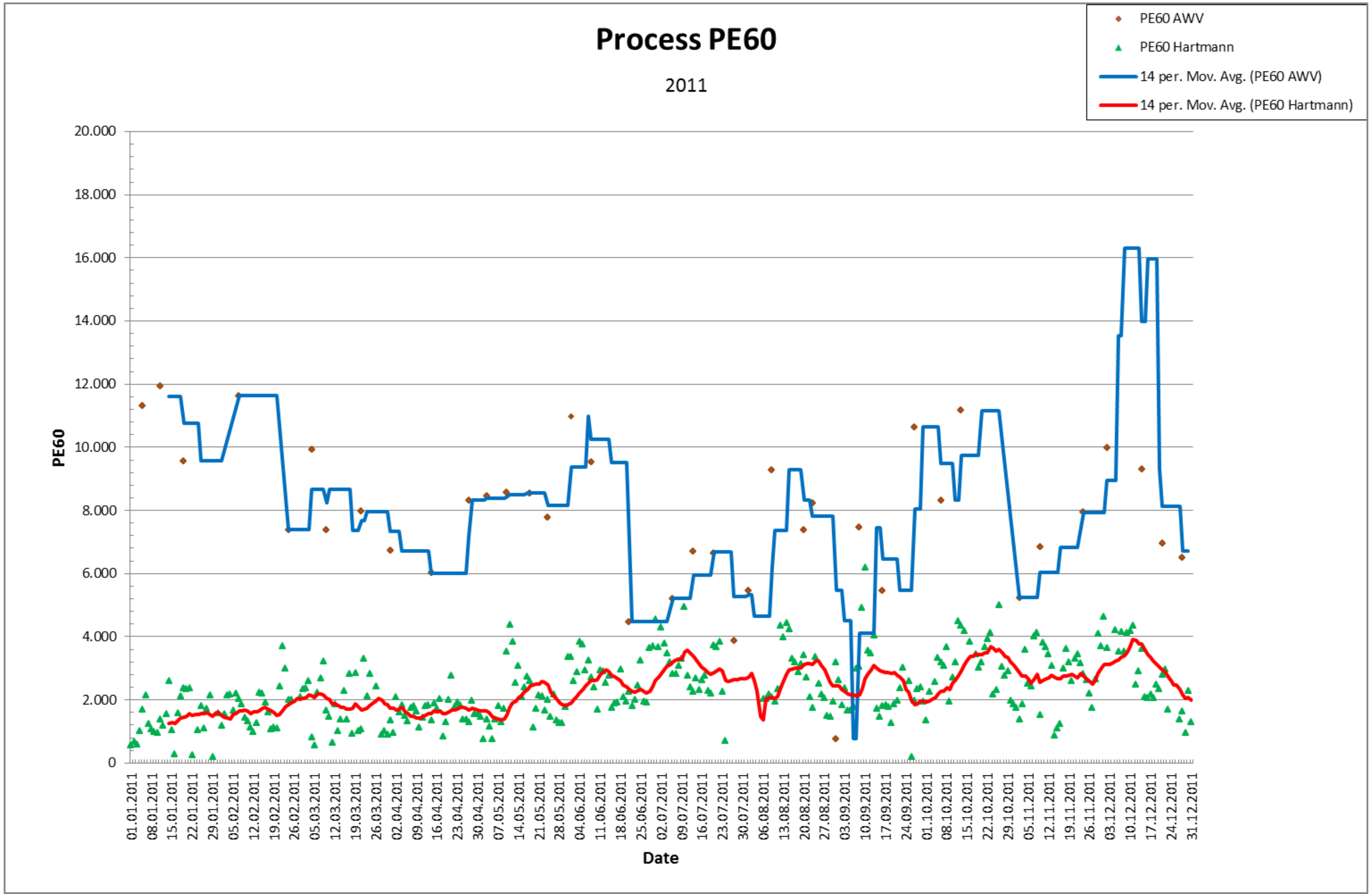


Figure 13: PE_{60} values 2010

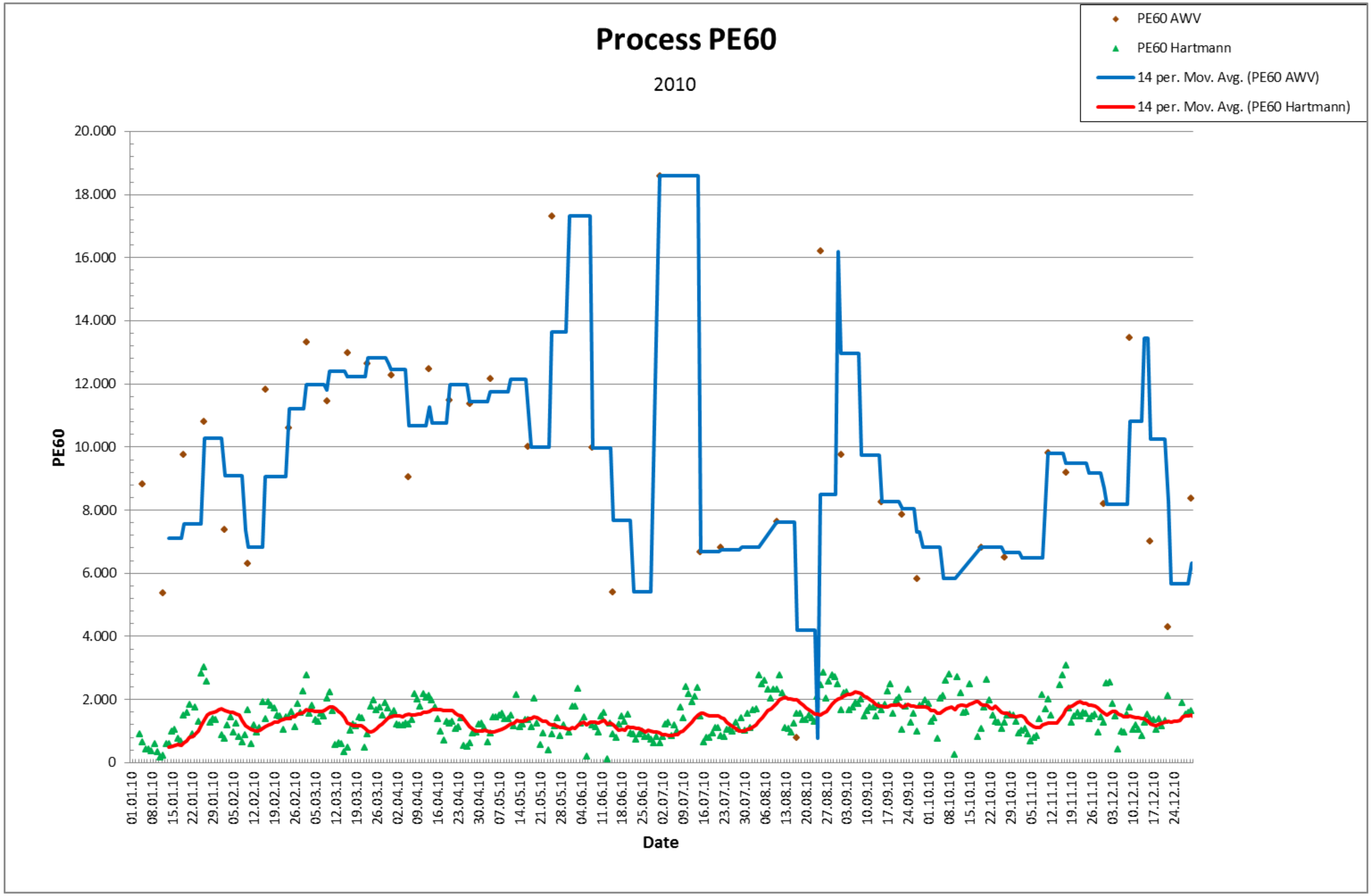


Figure 14: BOD_5 values 2012

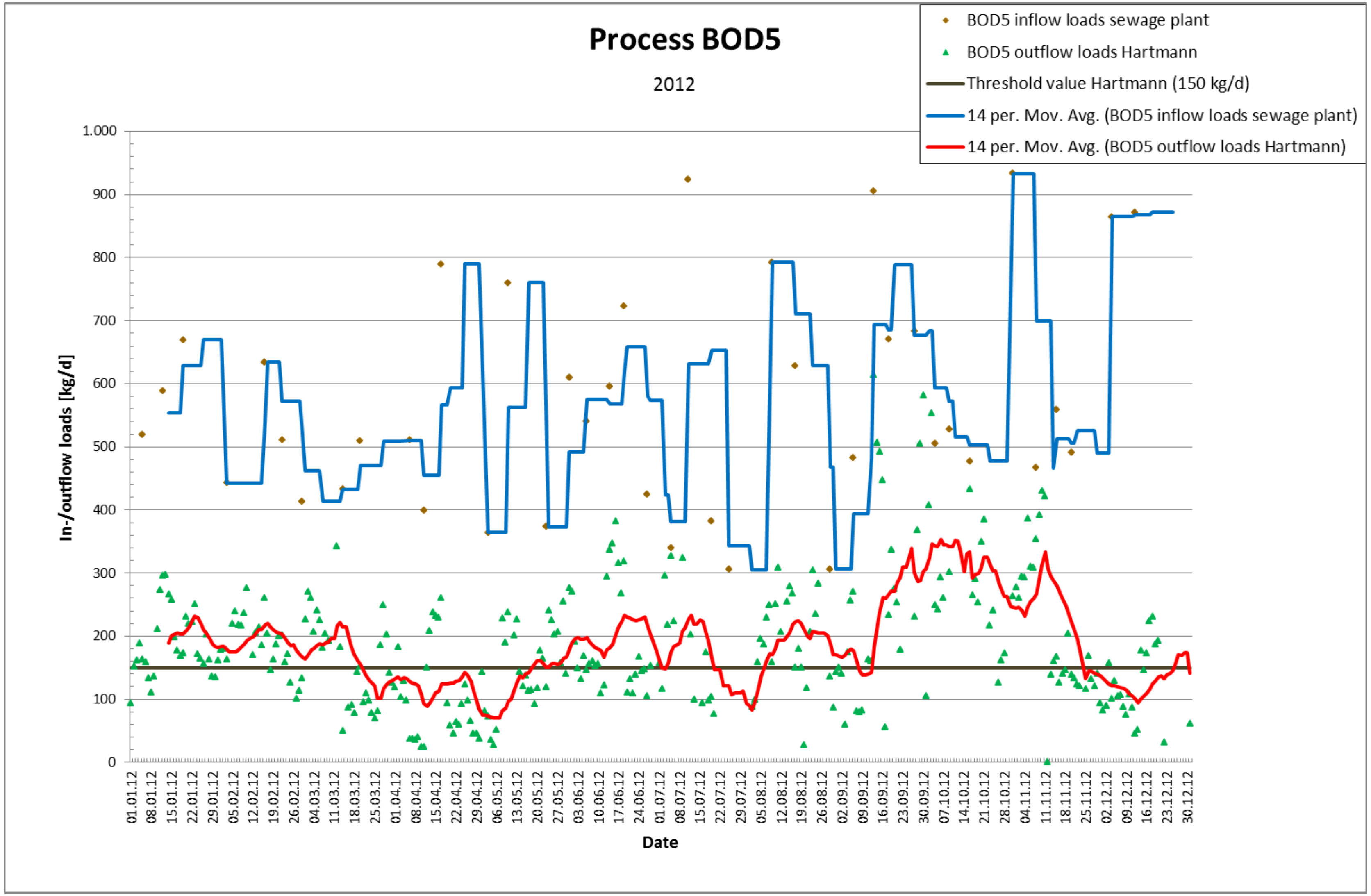


Figure 15: BOD_5 values 2011

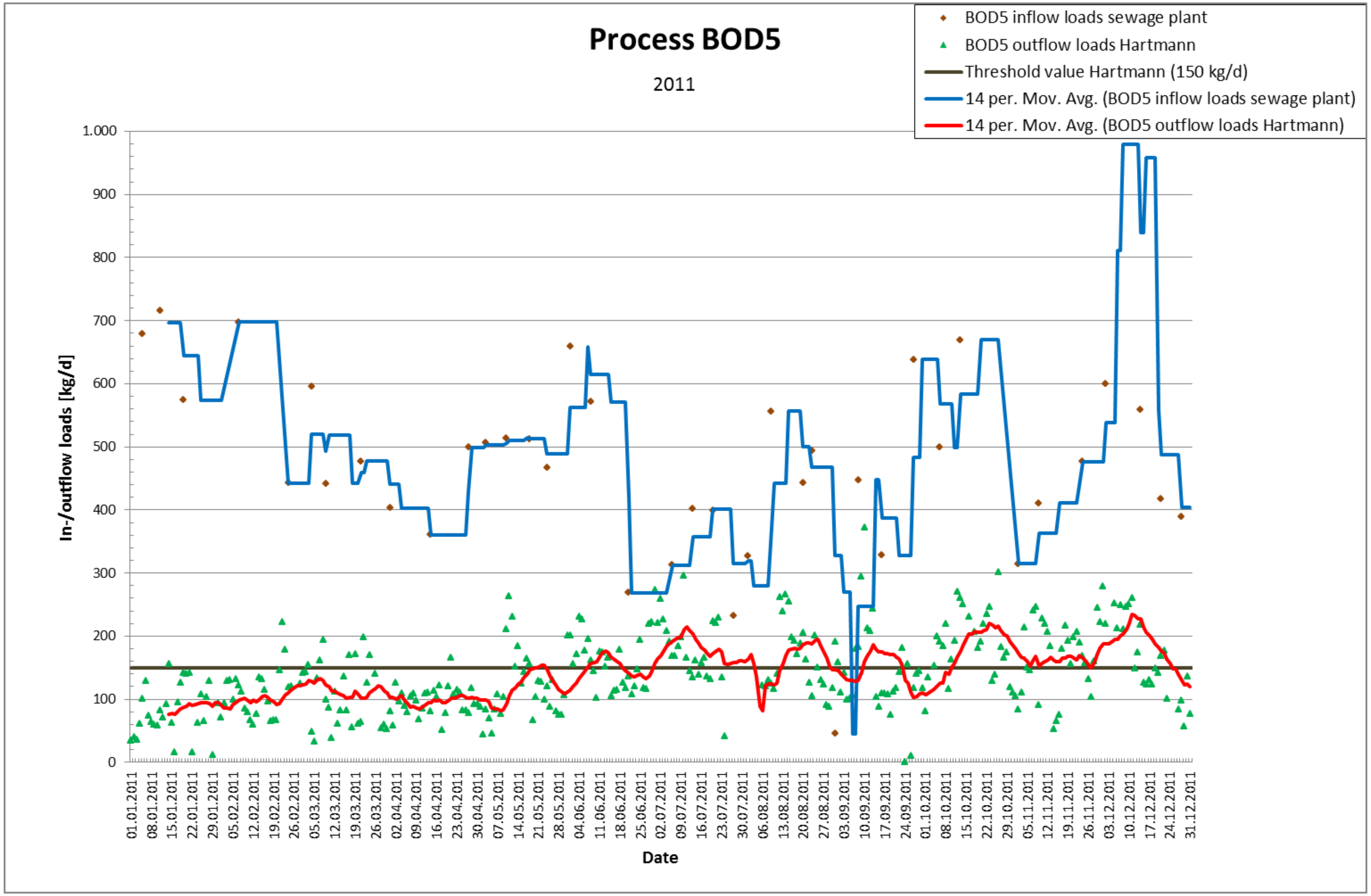


Figure 16: BOD_5 values 2010

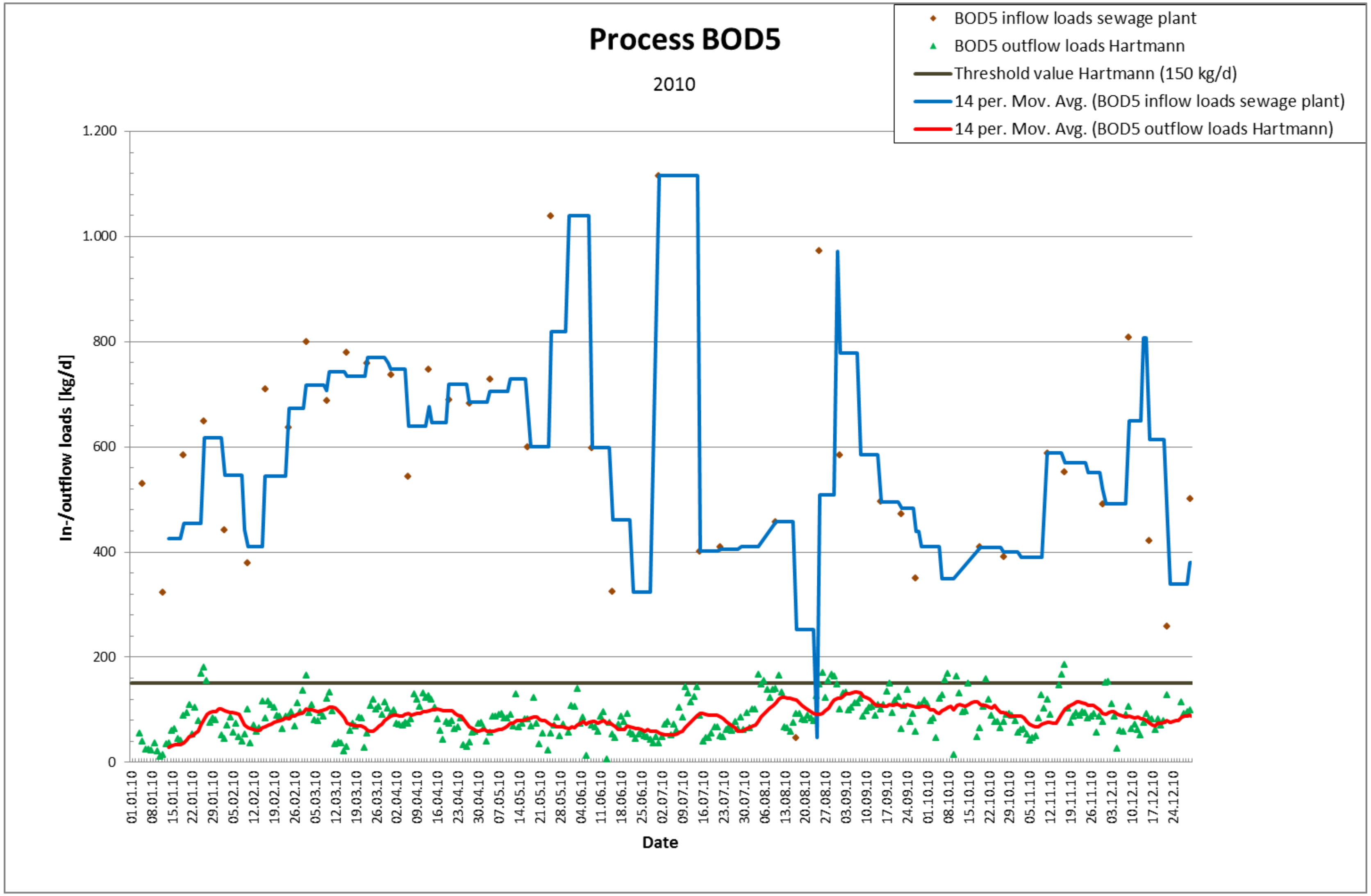
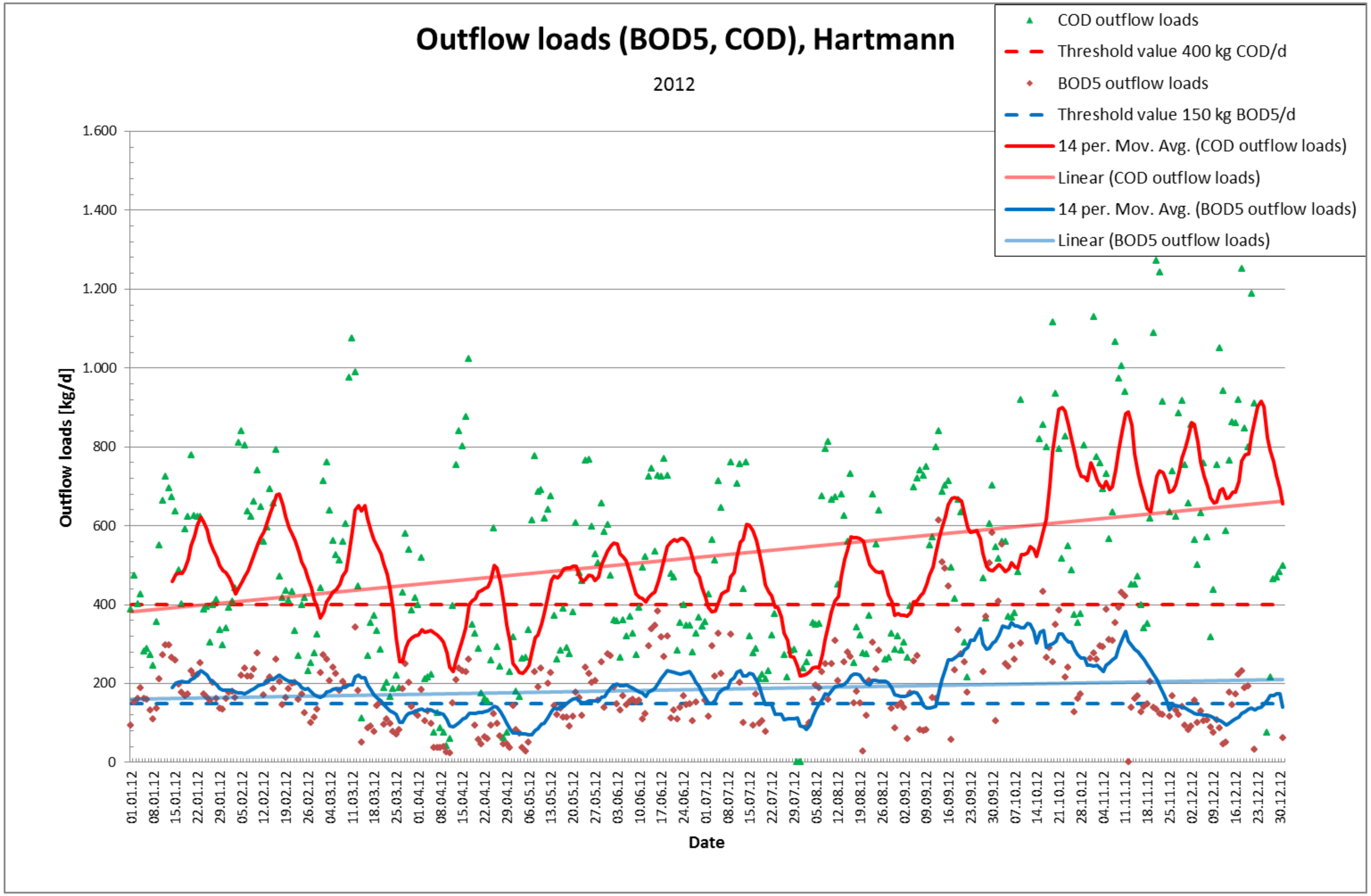


Figure 17: BOD_5 and COD outflow loads Hartmann 2012



5.2.3 PE_{120}/COD

In figure 18 to 20, you can see the outflow of the Paul Hartmann GmbH (red) and the inflow loads (blue) of the sewage treatment plant loads calculated as PE_{120} (red). As mentioned in Chapter 5.2 **there are only few COD values analyzed in the inflow of the municipal sewage treatment plant, nevertheless it can be seen that the COD loads show an almost parallel tendency.**

According to assessment No. NKW2-WA-0496/002 the Paul Hartmann GmbH is allowed to discharge max. 400 kg COD/d to the municipal sewage treatment plant. This limit was partially massively exceeded since 2010, as can be seen in figure 18 – 20. In 2012 the transgression was even by approx. 280 kg COD/d and one can clearly see the drastic increase of COD loads (red) based on the increasing linear trendline (see figure 17).

Figure 18: PE120 values 2012

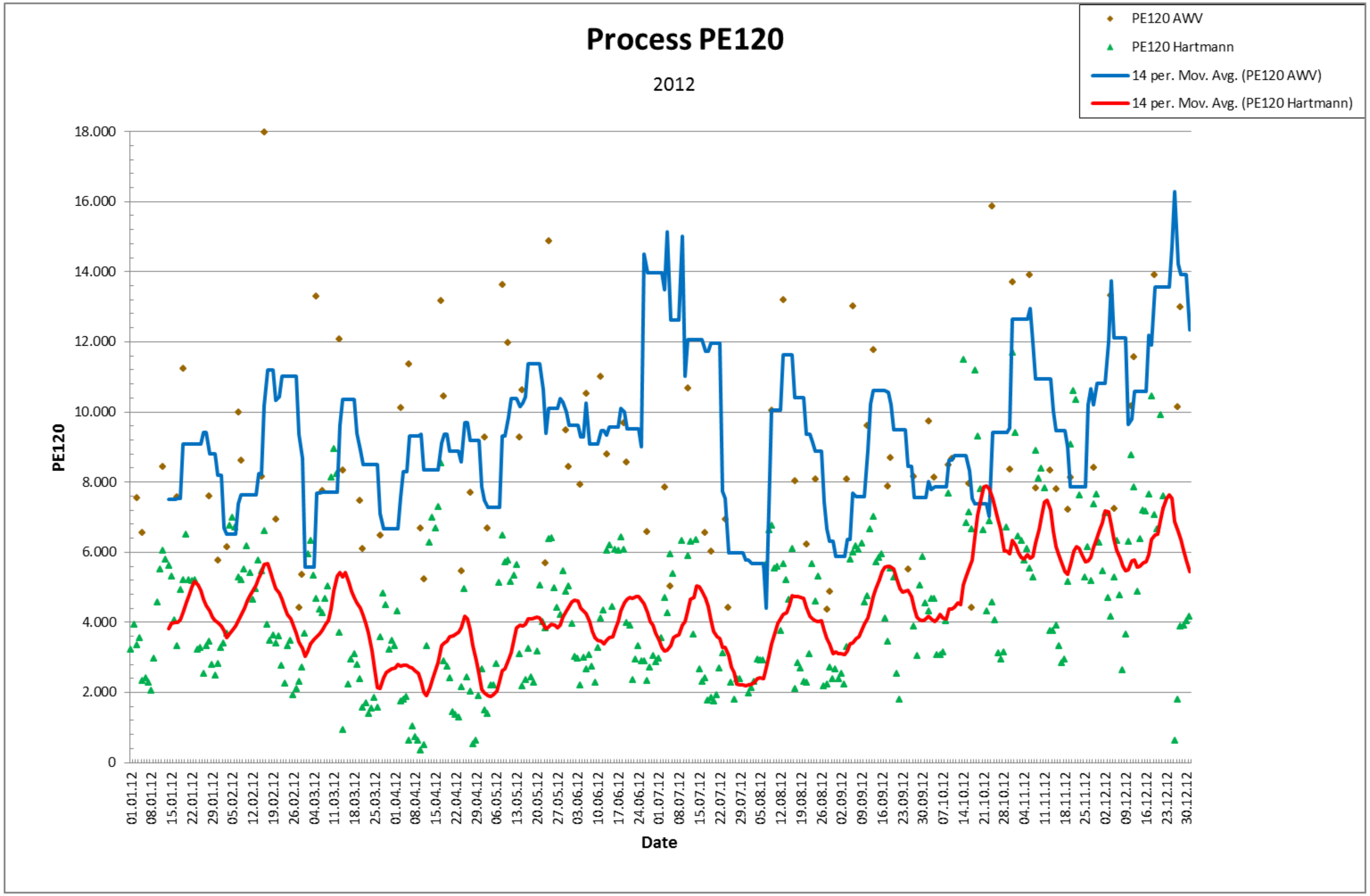


Figure 19: PE120 values 2011

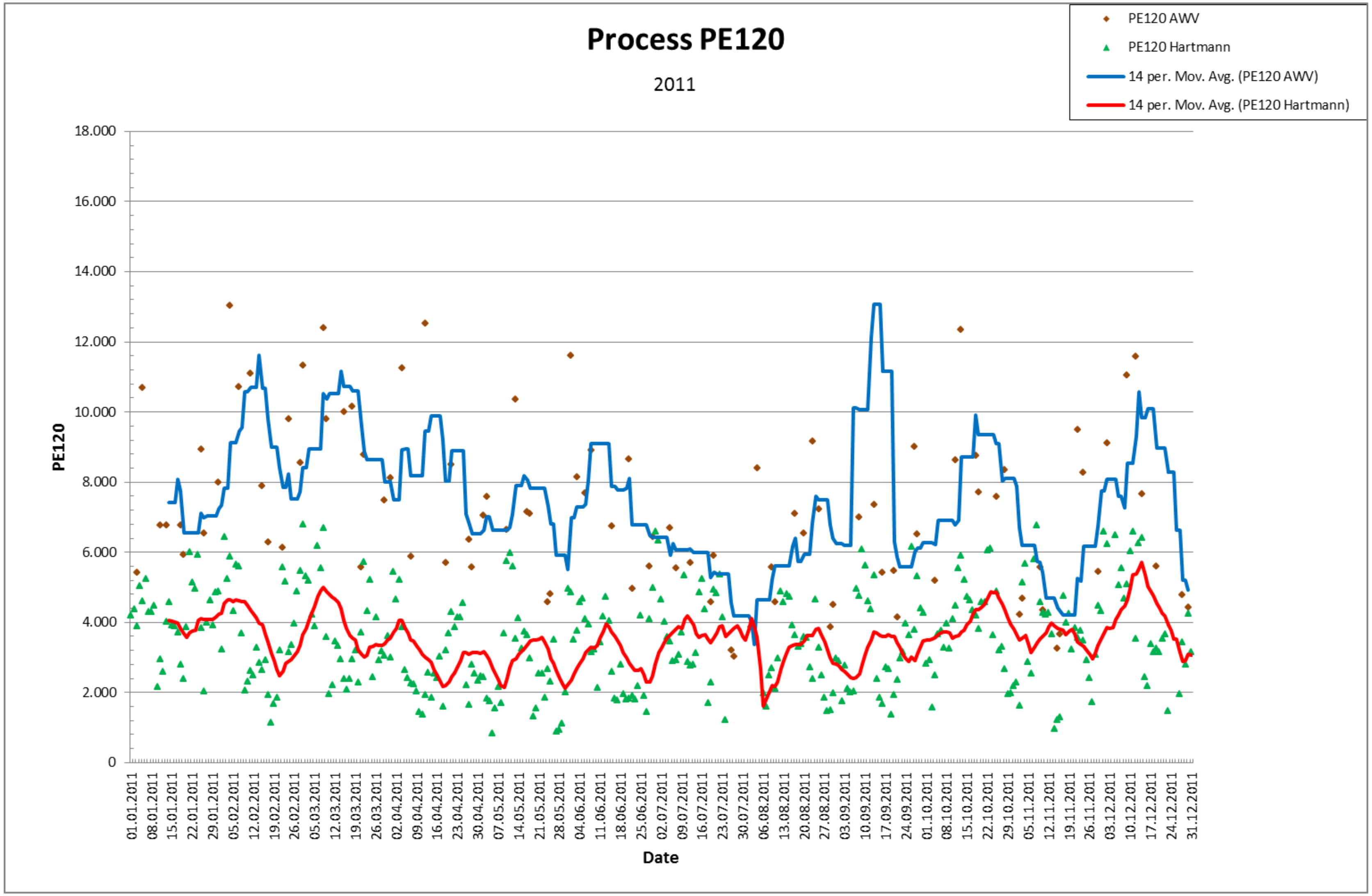


Figure 20: PE120 values 2010

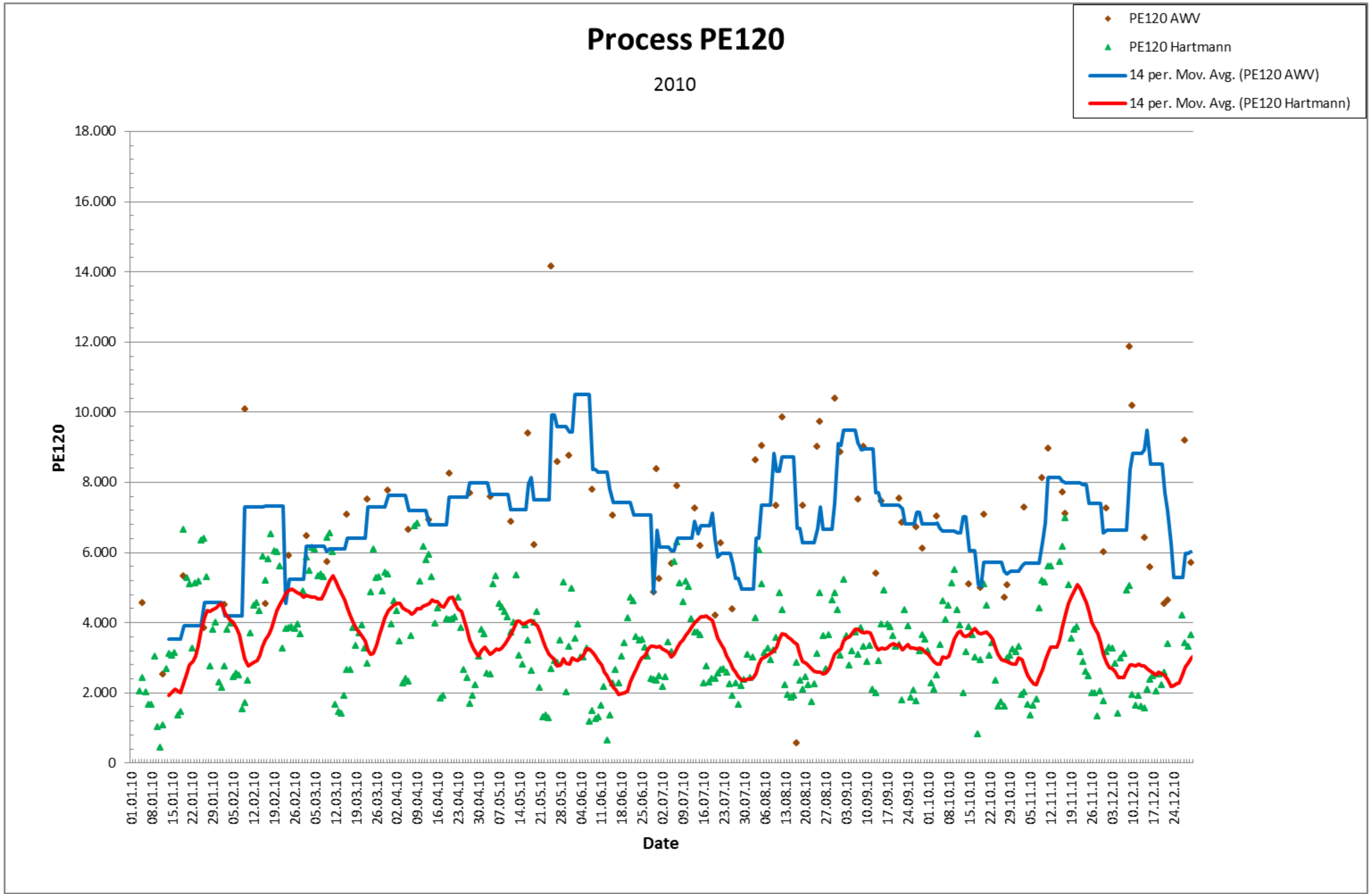


Figure 21: COD values 2012

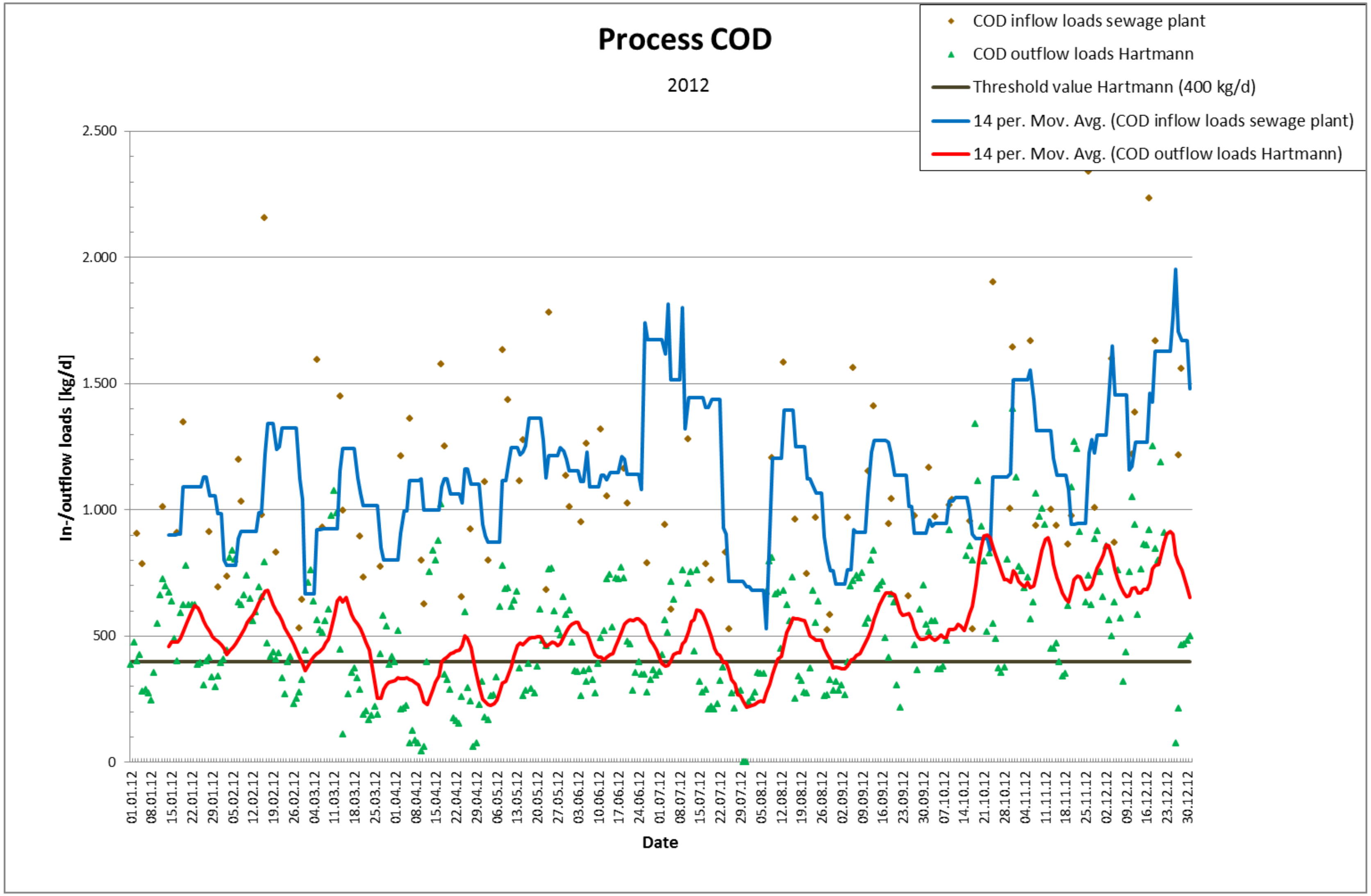


Figure 22: COD values 2011

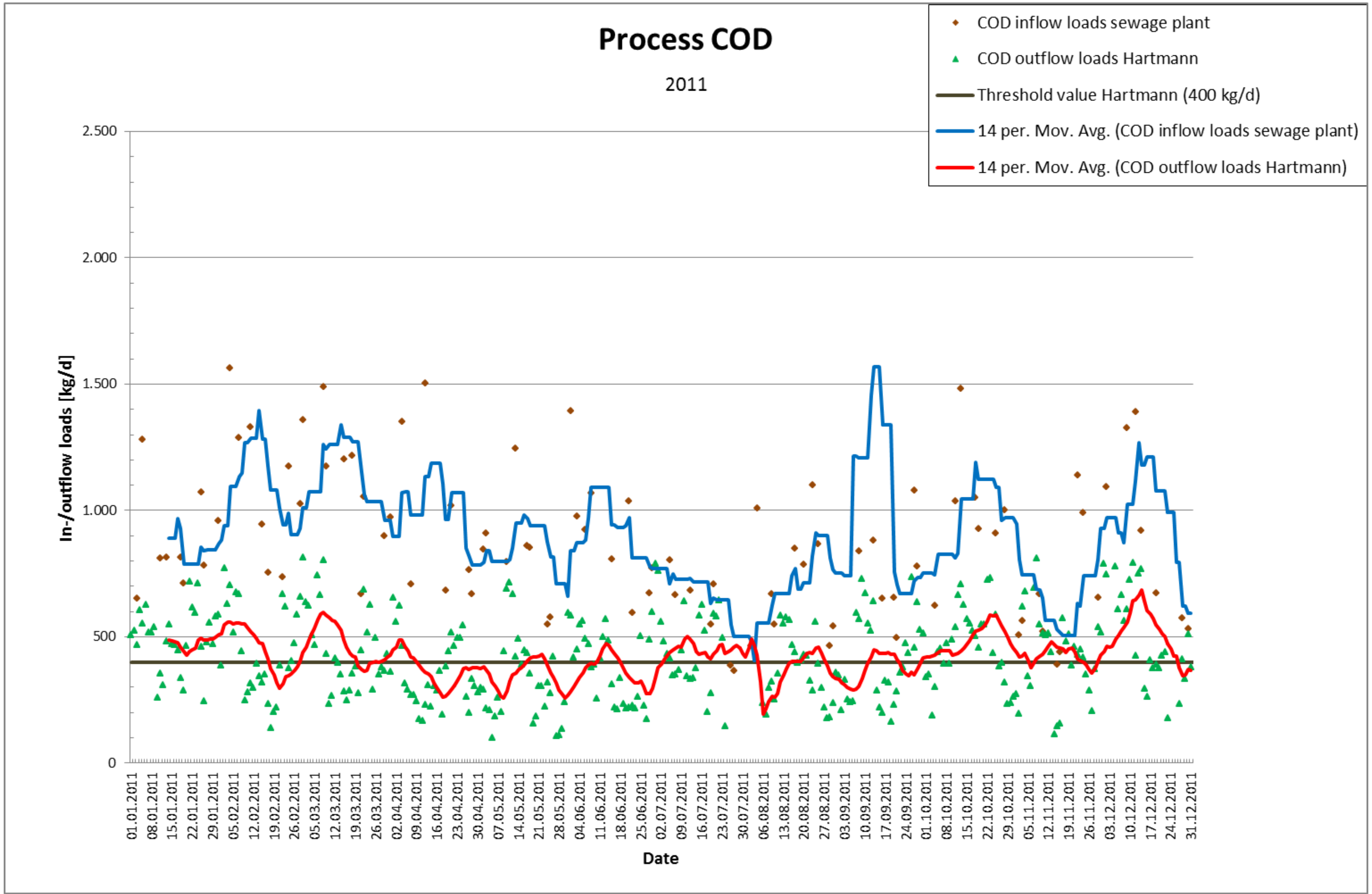
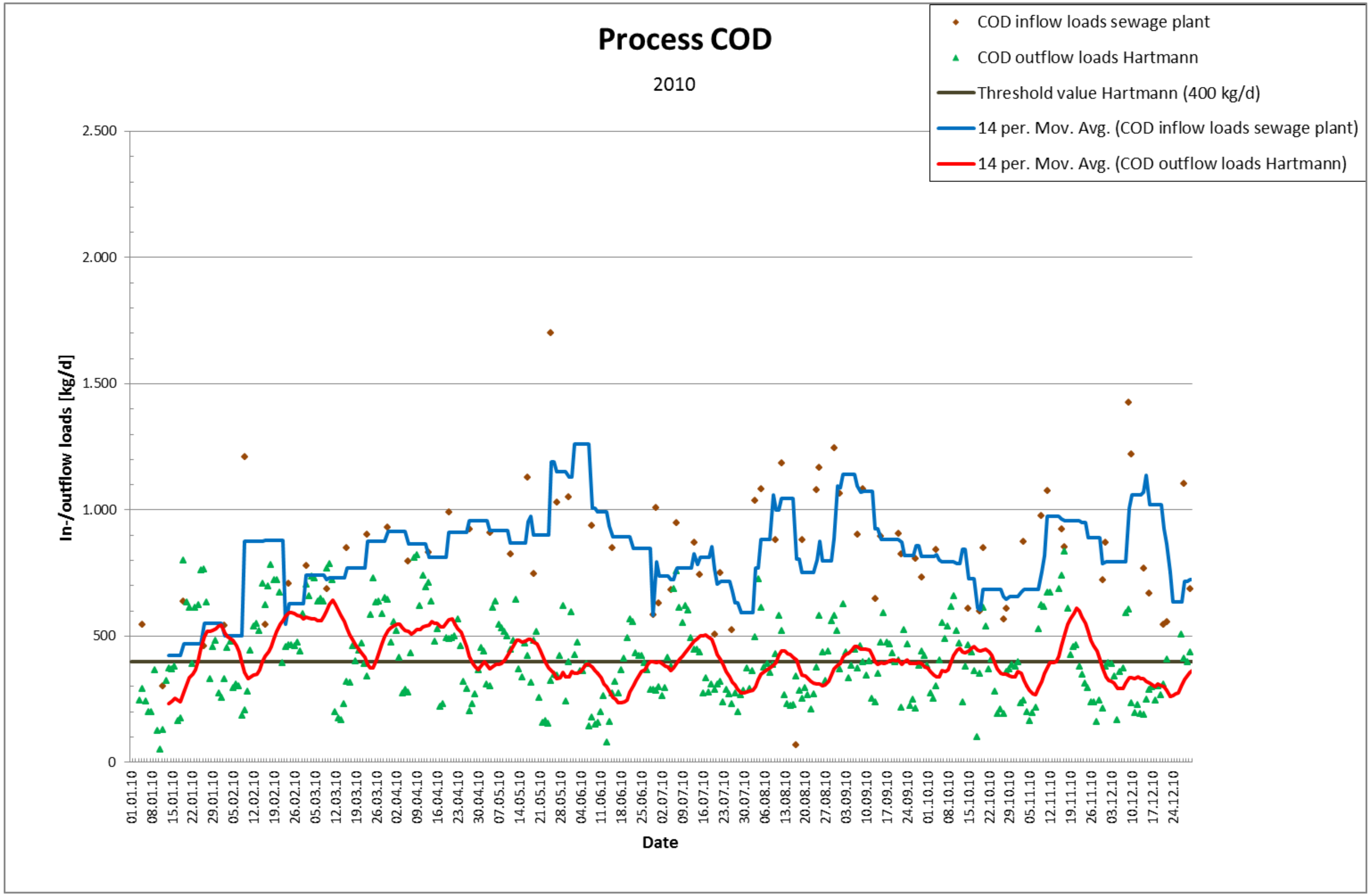


Figure 23: COD values 2010



5.2.4 Correlation of the outflow loads of the Paul Hartmann GmbH and the inflow loads to municipal sewage plant (regression analysis BOD_5/COD)

Figure 24 shows a regression analysis of the BOD_5 outflow loads of the Paul Hartmann GmbH compared to the inflow loads to municipal sewage plant. The strong dispersion of the values and the extremely low coefficient of determination (R^2 <0.1) of the logarithmic trendline indicates that the outflow loads discharged from the Paul Hartmann GmbH and the inflow loads to the municipal wastewater treatment plant do not correspond.

This is probably due to the fact that shock loads caused by rinsing of the sewer system during storm water flow have a big influence total inflow to the municipal wastewater plant.

Figure 27 shows a comparison of the measured effluent COD loads of Paul Hartmann GmbH to the inflow loads of the sewage plant. Moreover this diagram shows a large dispersion of the values and a very low regression coefficient of the logarithmic trendline (R^2=0.1595), which again indicates that there is no or only a very poor correlation between the COD values.

Based on these results no direct correlation between the outflow loads of the Paul Hartmann GmbH and the fluctuating inflow loads to the sewage plant can be identified. According to this it is rather unlikely that shock loads of BOD_5/COD in the inflow to the sewage plant are caused by the Paul Hartmann GmbH. Notwithstanding those findings the statement remains that the BOD_5/COD loads in the outflow of the Paul Hartmann GmbH have almost doubled between 2010 and 2012.

The regression analysis for the years 2010 and 2011 (see figures 25, 26, 28 and 29) exhibit high dispersion of the values and very low coefficients of determination, which also indicate that there is no direct link between the shock loads to the sewage plant and the outflow loads of the Paul Hartmann GmbH.

Figure 24: Regression analysis BOD_5 2012

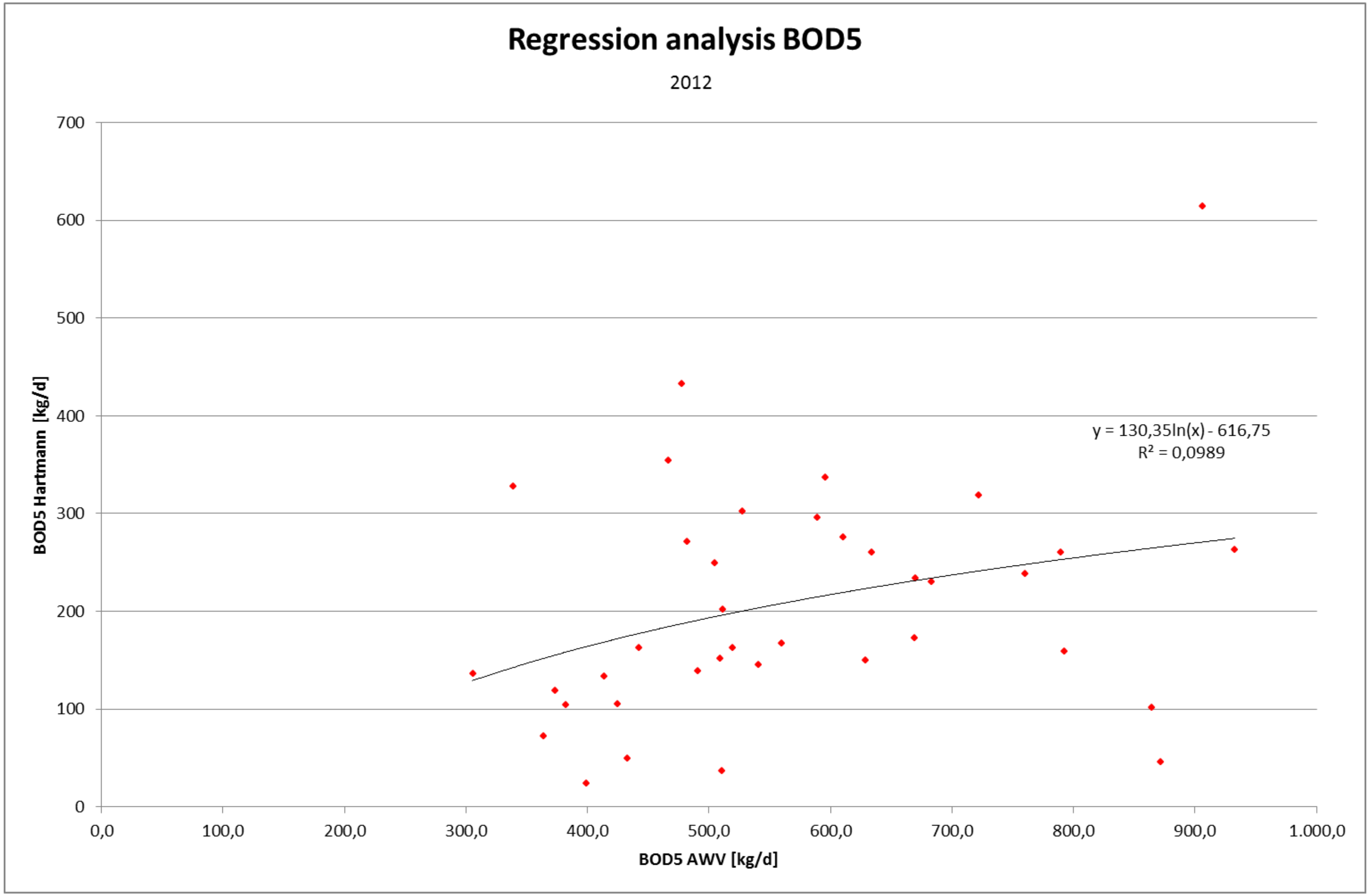


Figure 25: Regression analysis BOD_5 2011

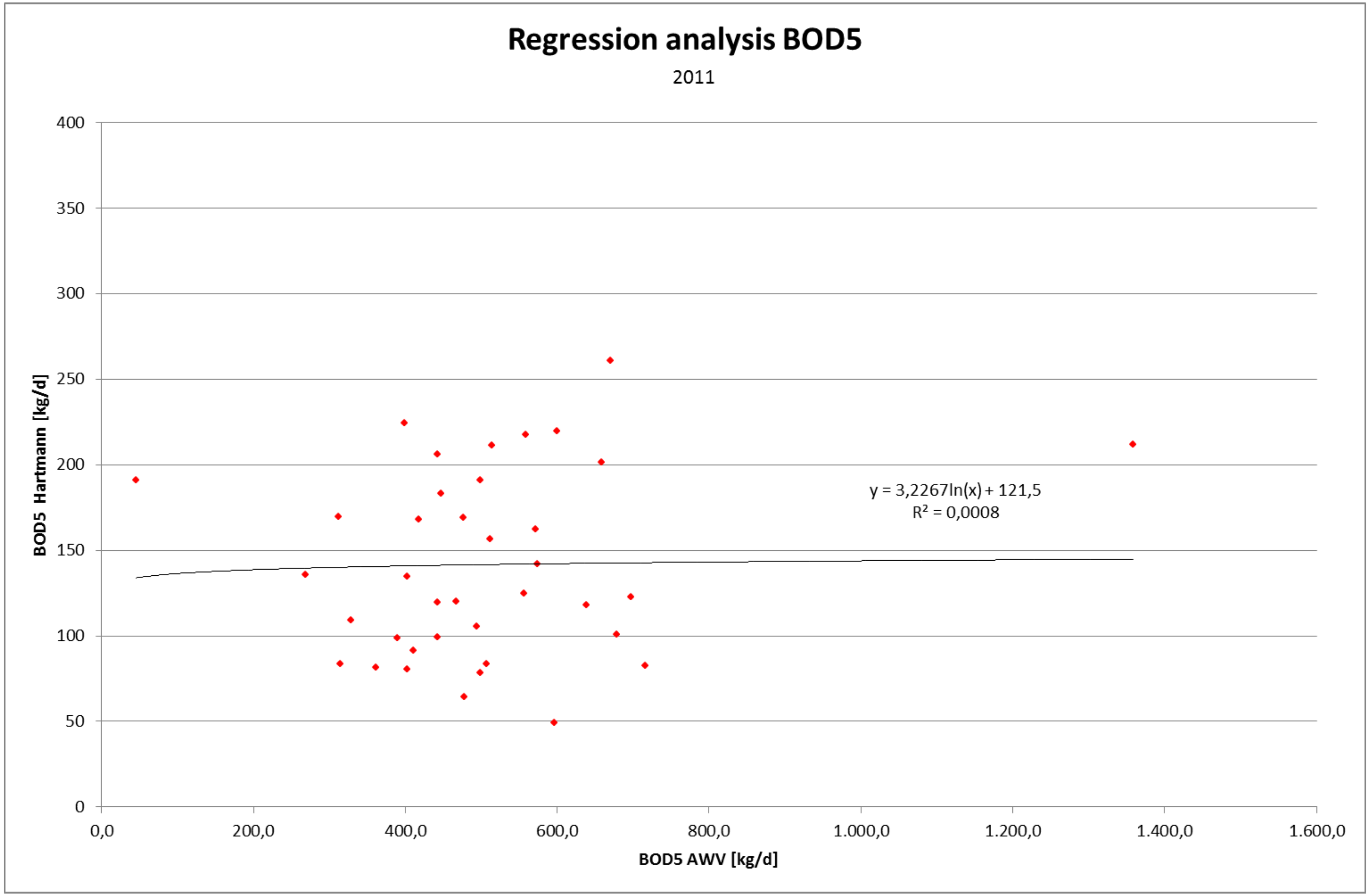


Figure 26: Regression analysis BOD_5 2010

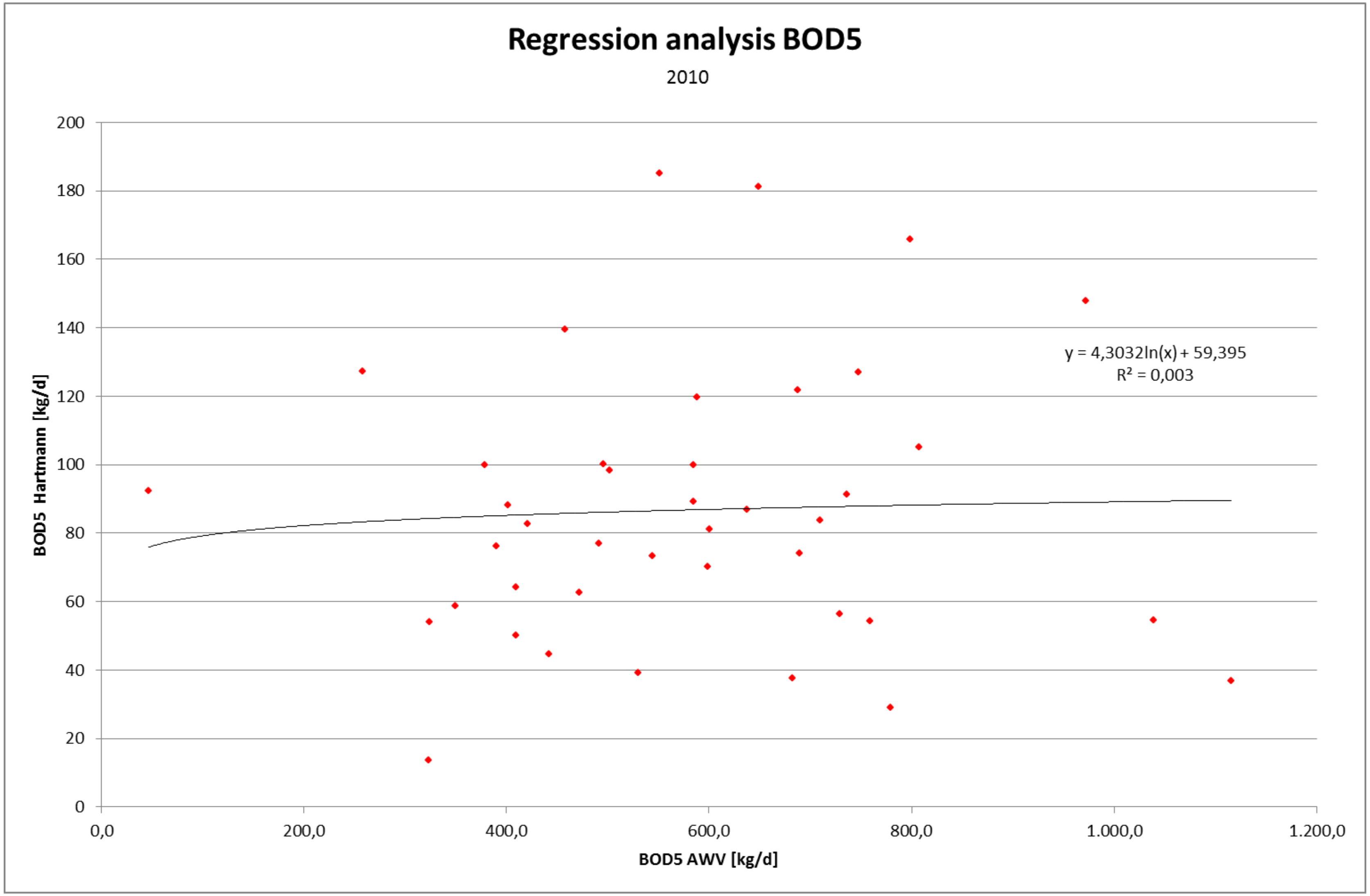


Figure 27: Regression analysis COD 2012

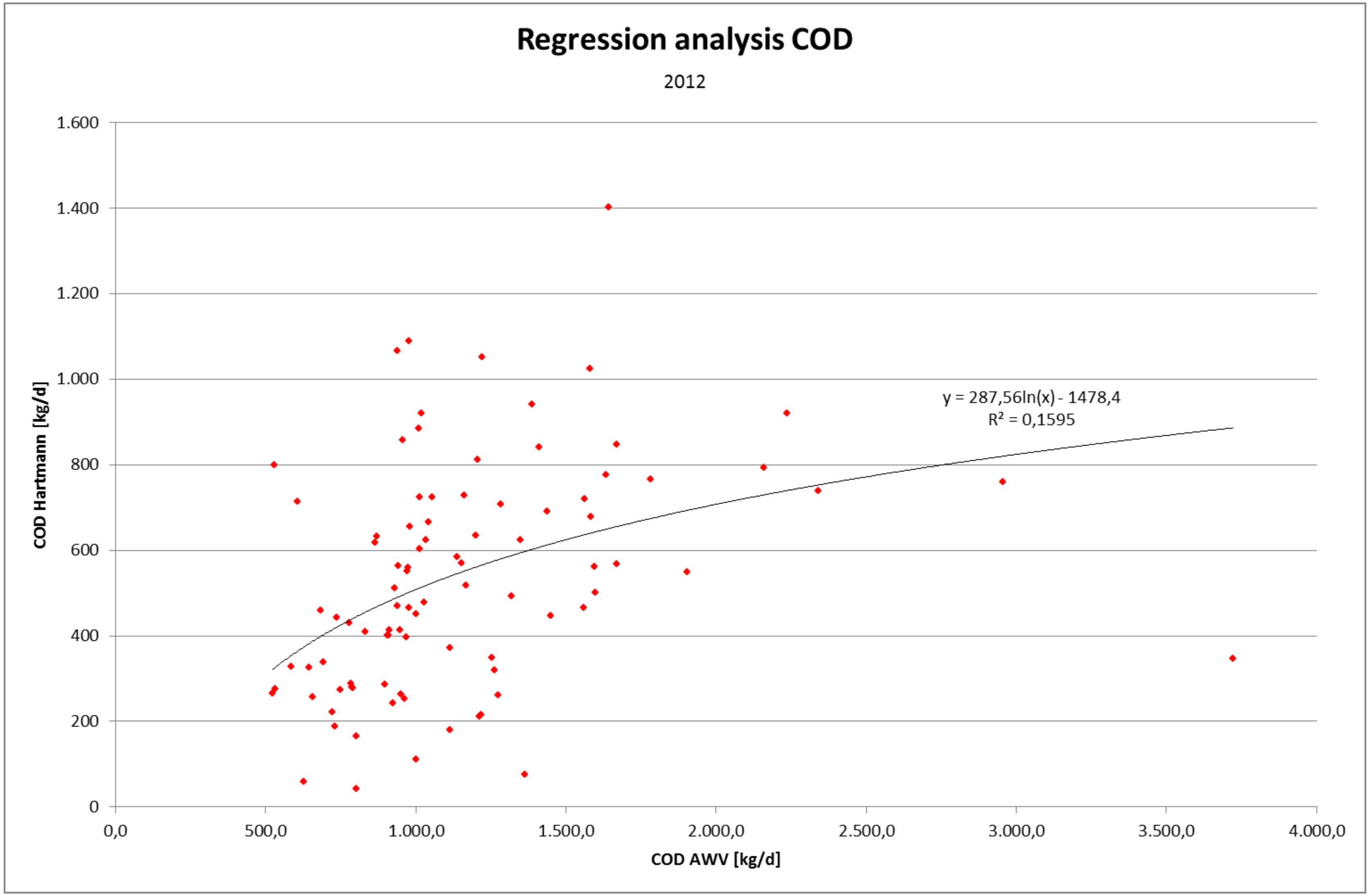


Figure 28: Regression analysis COD 2011

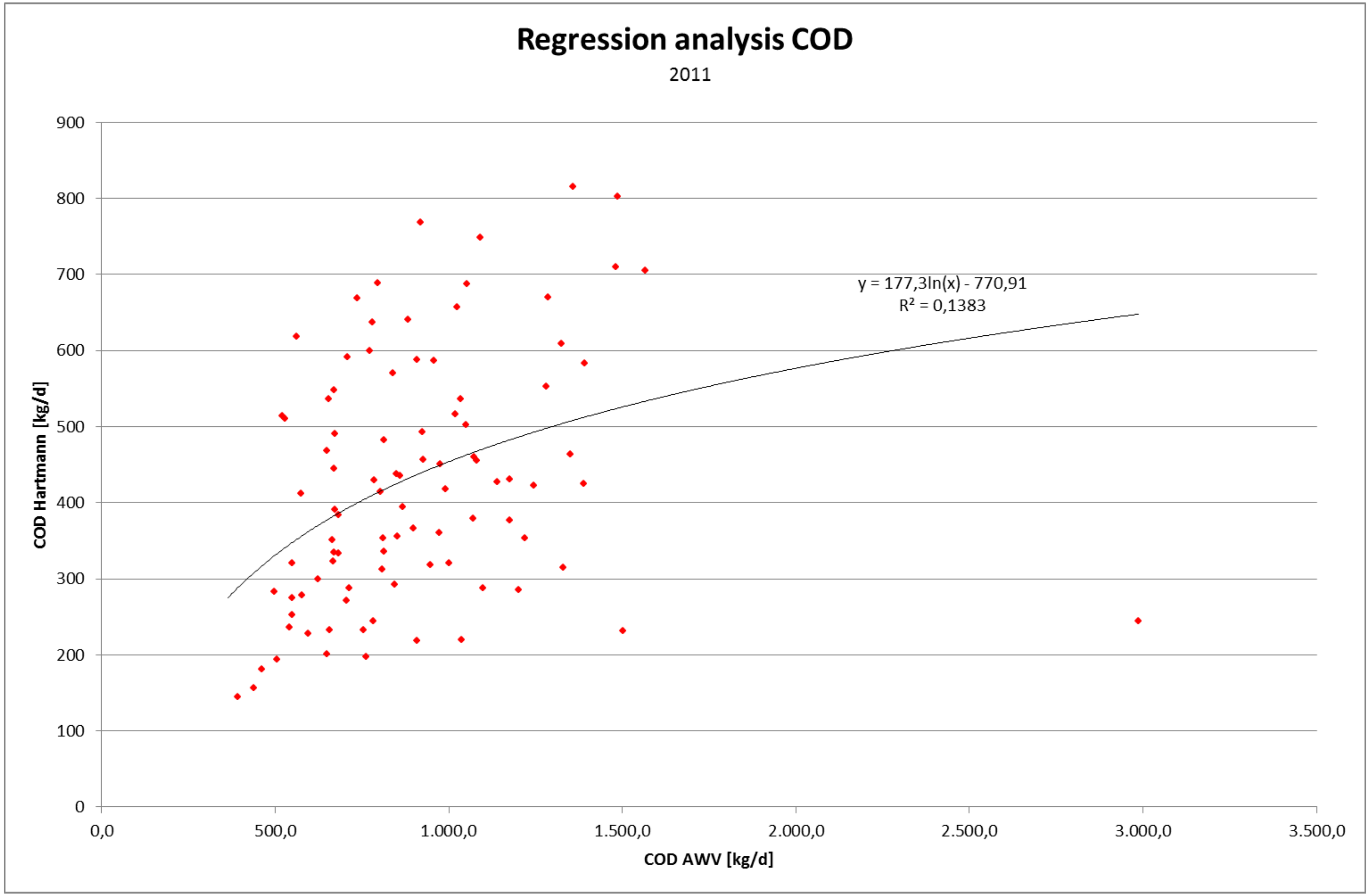
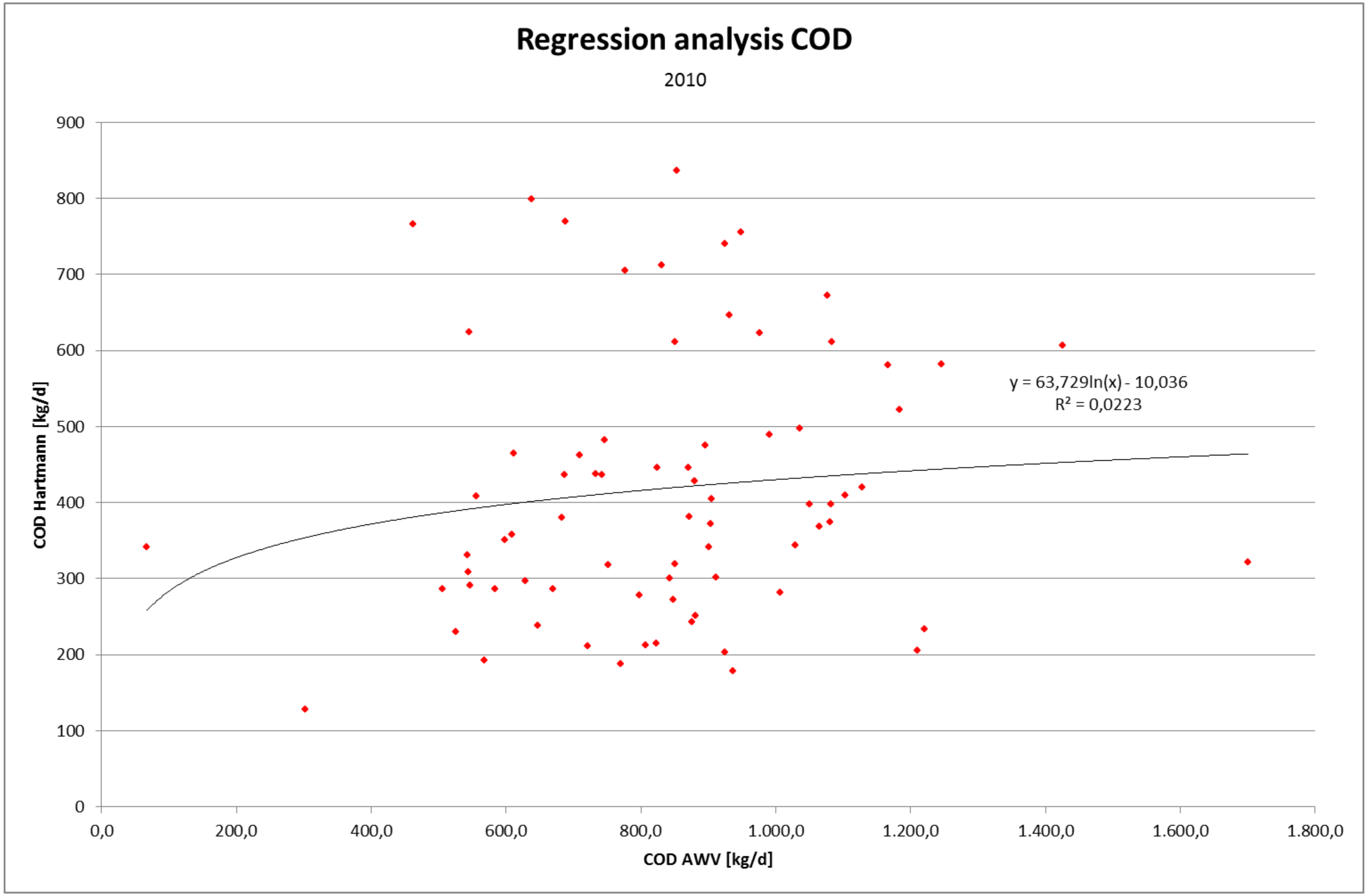


Figure 29: Regression analysis COD 2010



5.2.5 85% Percentile

For the classification of the wastewater treatment plant according to Annex 1 of the "1. Austrian Waste Water Ordinance" and to determine the design capacity of the municipal wastewater treatment plant, a specific design value, the BOD load in the inflow to the biological stage $L_{d,BOD,I}$ in kg BOD/d, is required. According to DWA ATV A 131, the design load has to be calculated from BOD_5 loads in the inflow to the WWTP as 85% Percentil, of all days with dry weather conditions, plus a scheduled reserve capacity.

For the design of the sewage treatment plant the following values from the inflow to the biological step are required:

- Relevant lowest and highest wastewater temperature. Calculation from the hydrograph of the 2 week means for two to three years.
- Relevant organic load ($L_{d,BOD}$, $L_{d,COD}$), the associated loads of suspended solids ($L_{d,DS}$) and phosphorus ($L_{d,P}$) to calculate the sludge production and thus the calculation of the volume of the aeration tank for the rated temperature .
- Relevant organic load and the nitrogen load to design of the aeration system for the (usually) highest relevant temperature
- Relevant concentration of nitrogen (C_N) and the corresponding concentration of the organic matter (C_{BOD}, C_{COD}) for the calculation of nitrate to be denitrified.
- Relevant concentration of phosphorus (C_P) for the determination of phosphorus to be eliminated.
- Maximum inflow during dry weather Q (m^3/h) for the design of anaerobic combined basin (optional) and the internal recirculation.
- Rated flow Q_m (m^3/h) for the design of the final clarification tank.

Daily loads can only be evaluated on the basis of volume or flow proportional 24-hour composite samples and the corresponding daily inflow rates.

The relevant loads are based on measurements on any day, which means that they have to be determined also under the inclusion of storm water conditions.

If an annual cycle of organic loads and/or the ratio of the organic load to the nitrogen load is available, several cases have to be investigated. The relevant concentrations should be calculated by reference to the relevant loads and the associated corresponding wastewater influent. The relevant loads have to be chosen according to the highest influent loads as average of a period corresponding to the sludge age. For nitrification and denitrification two-week-means can be used as simplified values. For sludge stabilization four-week-means can be used. Week-means cannot be formed, if there is an insufficient number of samples (there should be at least four values for daily loads per week).

Diagrams of the 85% Percentile which is calculated from the measured values from the Paul Hartmann GmbH referring BOD_5/COD and PE_{60}/PE_{120} are shown in figure 30 and 31. Table 3 is a compilation of the 85% percentiles of the years 2010 to 2012 and further statistical characteristics.

The corresponding values of the wastewater treatment plant are shown in table 4 and figure 32 and 33.

In table 3 and 4 the values of the statistical analysis of the daily measured values are compiled. The table shows, that the BOD_5 and COD loads for the Paul Hartmann GmbH were exceeds he loads accepted by the authority on average by approx. 23% (BOD_5) and 30% (COD) in 2012. The max. peak values exceeds the limit values up to 81% (BOD_5) and 93% (COD).

Figure 30: 85% Percentile PE_{60}/PE_{120} (Hartmann 2012)

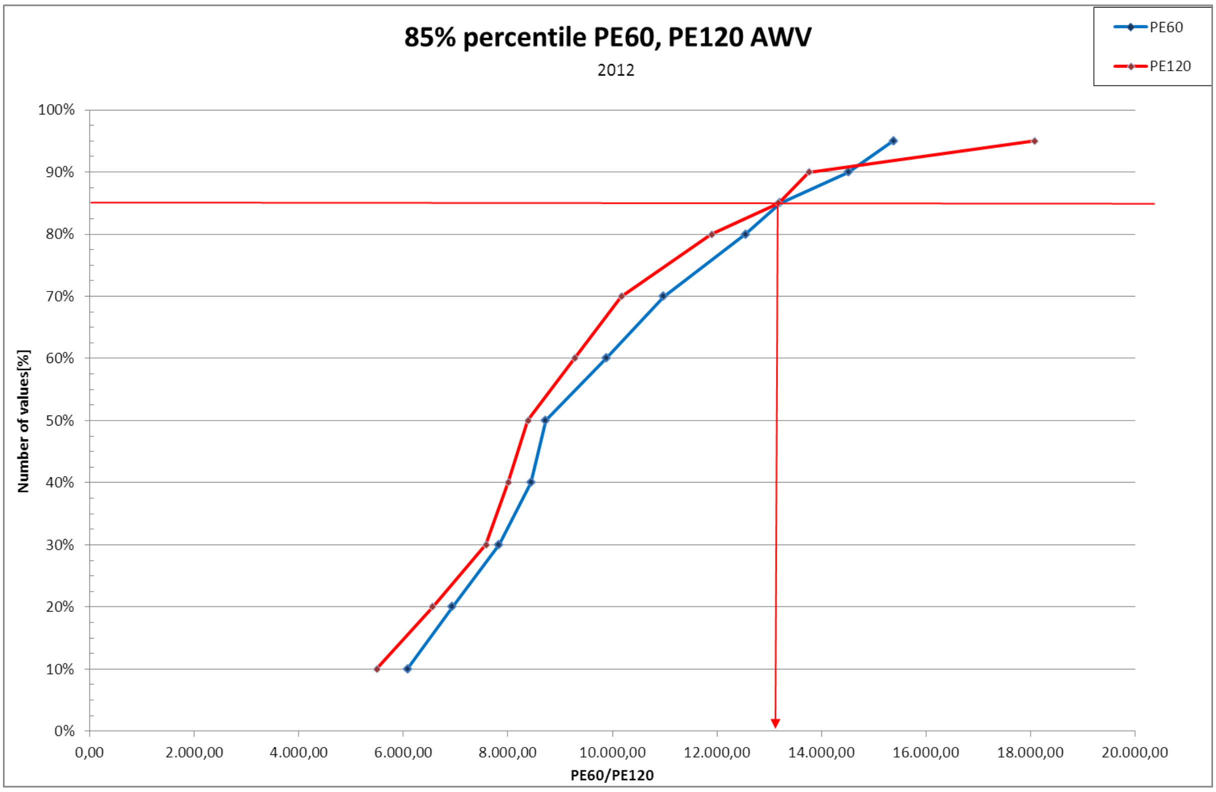


Figure 31: 85% Percentile BOD_5/COD (Hartmann 2012)

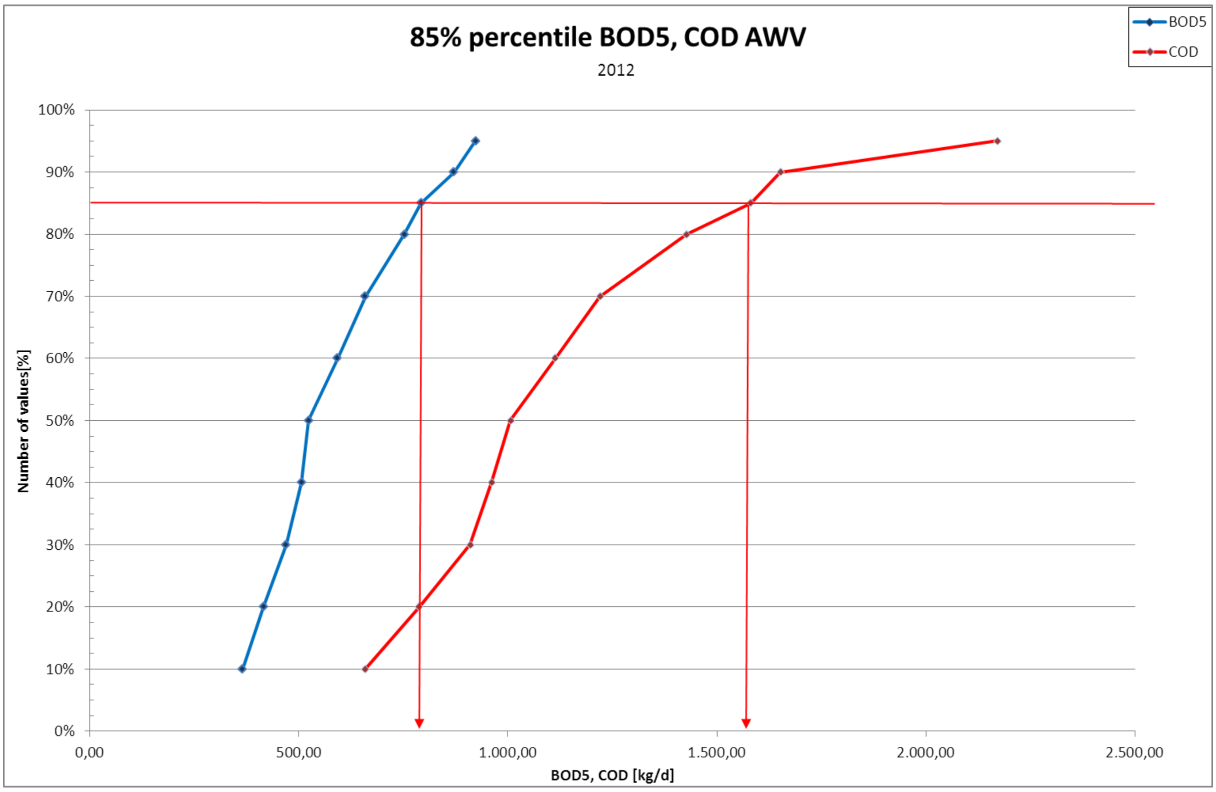


Table 3: Compilation of statistical characteristics of the analyzed wastewater loads (Hartmann)

	BOD_5 [kg/d]			COD [kg/d]			PE_{60}			PE_{120}		
Year	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
Number	349	338	306	358	348	342	349	338	306	356	348	343
Min	6	11	24	52	100	42	98	180	404	435	836	352
Max	185	372	614	837	815	1402	3085	6195	9690	6972	6793	11684
Mean	85	140	185	410	425	521	1422	2332	3057	3419	3539	4367
Median	83	130	166	391	417	482	1384	2173	2745	3260	3473	4024
Standard dev	35	61	99	165	165	254	583	1014	1601	1376	1378	2126
85% percentile	122	210	272	613	610	770	2033	3494	4516	5111	5079	6441

Table 4: Compilation of statistical characteristics of the analyzed wastewater loads (AWV)

	BOD_5 [kg/d]			COD [kg/d]			PE_{60}			PE_{120}		
Year	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
Number	41	40	40	75	98	96	41	40	40	75	98	96
Min	47	46	305	67	364	524	777	762	5091	560	3030	4366
Max	1116	1359	933	1700	2988	3721	18592	22649	15551	14168	24901	31012
Mean	578	493	573	839	894	1140	9631	8212	9553	6990	7446	9500
Median	585	477	523	850	842	1006	9749	7950	8724	7086	7020	8386
Standrad dev	209	195	175	251	354	495	3486	3242	2910	2092	2947	4124
85% percentile	773	656	792	1082	1223	1581	12889	10930	13206	9015	10189	13174

5.3 Statement of reason for increased wastewater loads from Paul Hartmann GmbH

5.4 Ratio of COD filtrate water to COD sediment

In a case study performed by the Paul Hartmann GmbH the COD concentration of the filtrate wastewater from the sludge dewatering plant was assumed as reason for the increasing wastewater loads. Therefore the filtrate wastewater from the filter pressed used for sludge dewatering and the settleable solids were analyzed for correlations.

The filtrate wastewater of the belt press was filtered by a circular paper filter. The settleable solids of the sample were separated from the remaining water, collected and diluted by distilled water 1:5 followed also by laboratory filtration. 2 ml of both filtrates were analyzed.

Table 5: Data for calculation of the COD ratio of filtrate wastewater/settleable solids

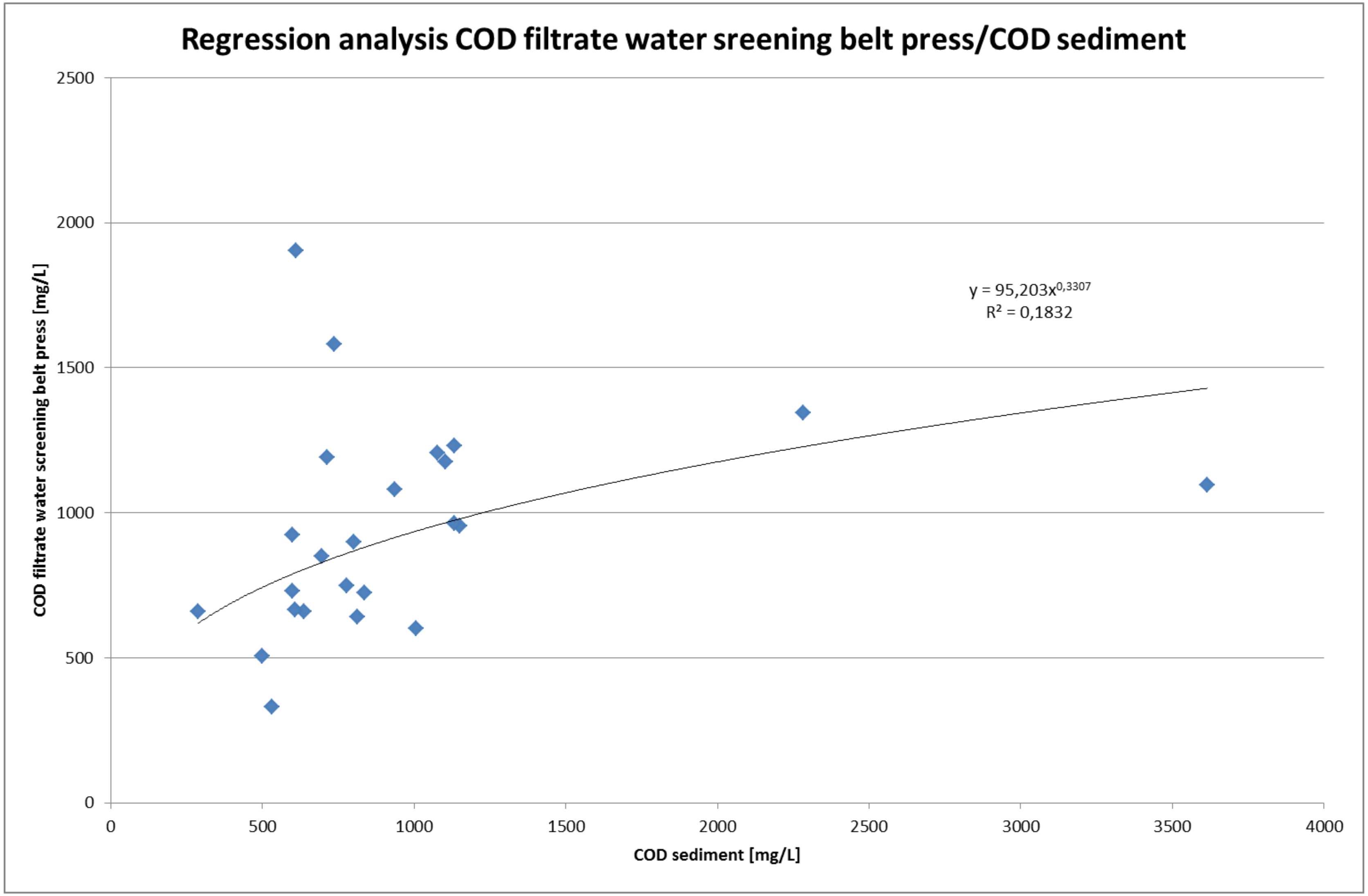
Date	Filtrate wastewater belt press COD [mg/l]	Settleable solids COD [mg/l]	Ratio of COD filtrate wastewater to COD settleable solids
17.01.2013	557	1680	1:3,00
23.01.2013	935	1079	1:1,15
28.01.2013	532	331	1:0,62
29.01.2013	779	750	1:0,96
30.01.2013	1151	955	1:0,83
31.01.2013	812	640	1:0,79
01.02.2013	637	660	1:1,04
04.02.2013	736	1580	1:2,15
05.02.2013	713	1190	1:1,67
06.02.2013	608	665	1:1,09
07.02.2013	610	1905	1:3,12
08.02.2013	599	925	1:1,54
12.02.2013	837	725	1:0,87
13.02.2013	1132	1230	1:1,09
14.02.2013	2282	1345	1:0,59
15.02.2013	800	900	1:1,12
18.02.2013	289	660	1:2,28
19.02.2013	498	505	1:1,01
20.02.2013	1008	600	1:0,59
21.02.2013	598	730	1:1,22
25.02.2013	695	850	1:1,22
26.02.2013	1132	965	1:0,85
27.02.2013	1104	1175	1:1,06
28.02.2013	1076	1205	1:1,12
01.03.2013	3615	1095	1:0,30

The results were compiled and compared (see table 5). The comparison of the ratios shows, that there is no indirect correlation between the COD analyzed in the filtrate from the settleable solids. (Hartmann, Ges.m.b.H, 2013) So neither an influence of the filtrate from the belt filter press nor from the filtrate of the settleable solids on the COD in the outflow could be confirmed (see figure 32).

Table 6: Statistical characteristics of COD filtrate wastewater and COD settleable solids

	Filtrate wastewater belt press COD [mg/l]	Settleable solids COD [mg/l]
Number	24	24
Min	289	331
Max.	3.615	1.905
Mean	966	944
Median	790	913
Standard dev.	667	351
85% Percentile	1136,75	1258,75

Figure 32: Regression analysis COD filtrate wastewater belt press/COD settleable solids



5.5 Effect of the use of wet strength agents on COD loads

5.5.1 Usage of wet strength agents

Wet strength agents are chemical additives for the paper industry, which are used to increase and obtain the strength of the paper during wet conditions. A treated paper is referred to as wet strength when its mechanical strength in the wet state is higher than the comparable wet strength of an untreated paper. Mainly polyamidoamine-epichlorohydrin (PAAE) resins are used as wet strength agents today. (BGK Paper Solutions, 2014)

A PAAE resin influences:

- wet strength
- retention
- trash fixation (anionic)
- performance of other additives,
  e.g. alkylated ketene dimer sizing
- adhesion at the Yankee cylinder (tissue)
- dry strength
- charge balance

5.5.1.1 Division

A simple classification of the wet strength papers can be made by differentiating between:

- **Low wet strength:** base papers, tissues
- **Medium wet strength:** towel crêpe, food packaging papers, coffee filters, liquid packaging board, cold store carton, wallpapers
- **High wet strength:** decorative paper, bank note paper, label papers, security papers

The wet strength, as result of a tensile test, is given either as absolute value in Newton or as ratio to the dry strength of the same paper in percent. (BGK Paper Solutions, 2014)

5.5.1.2 Mechanism of wet-strengthening

The strength properties of paper are mainly determined by the formation of hydrogen bonds that form at contact points of the fiber surfaces when water is removed. These hydrogen bonds are relatively easily cleaved by water, so dry papers loose its strength if they are brought in contact with water. All strength properties of the paper can be removed by solution of the hydrogen bonds by complete wetting of the paper. The wet strength agents are added to the paper pulp and develop a more solid (preferably covalent) bond to the fibers, that cannot be displaced by water molecules. Wet strength resins are cationic and thus quickly absorbed on the fibers. During paper drying, these products react chemically with themselves and also with the hydroxyl and carboxyl groups on the fiber surface. These reactions are caused by temperature increase and concentration. Since these bonds are formed only under the drying conditions, they are not cleaved by water. Because of this wet strength finished paper still shows part of the strength properties of the dry condition when wet. (BGK Paper Solutions, 2014)

5.5.1.3 Production

PAAE resins are produced in several synthesis steps. At first the basic framework is synthesized in a polycondensation from dicarboxylic acids (mainly adipic acid) and primary and secondary amines, ethylenediamine and diethylenetriamine being of major importance in this respect. In a next step, the poly-condensate is transformed in aqueous solution with epichlorohydrin which results in the formation of reactive groups (epoxide and azetidinium groups) at the parent structure. By adjusting to a weak acid pH value, the resin solutions such produced are prevented from self-cross-linking and are stabilized. Commercially available products contain between 12.5 and 25 % of active ingredient; above this percentage, no highly effective and at the same time storage-stable products are available.

In practice, depending on the conditions, there are often with the same active ingredient content of PAAE resins very different effects in a given material system. PAAE resins are continuously developed by varying the ratios of its components and the synthesis parameters. (BGK Paper Solutions, 2014)

5.5.2 Effects of wet strength agents on the COD

In order to check the correlation between the increased COD loads and the used wet strength agent the measured values of the COD in the effluent of 2013 are represented in the diagram in figure 33.

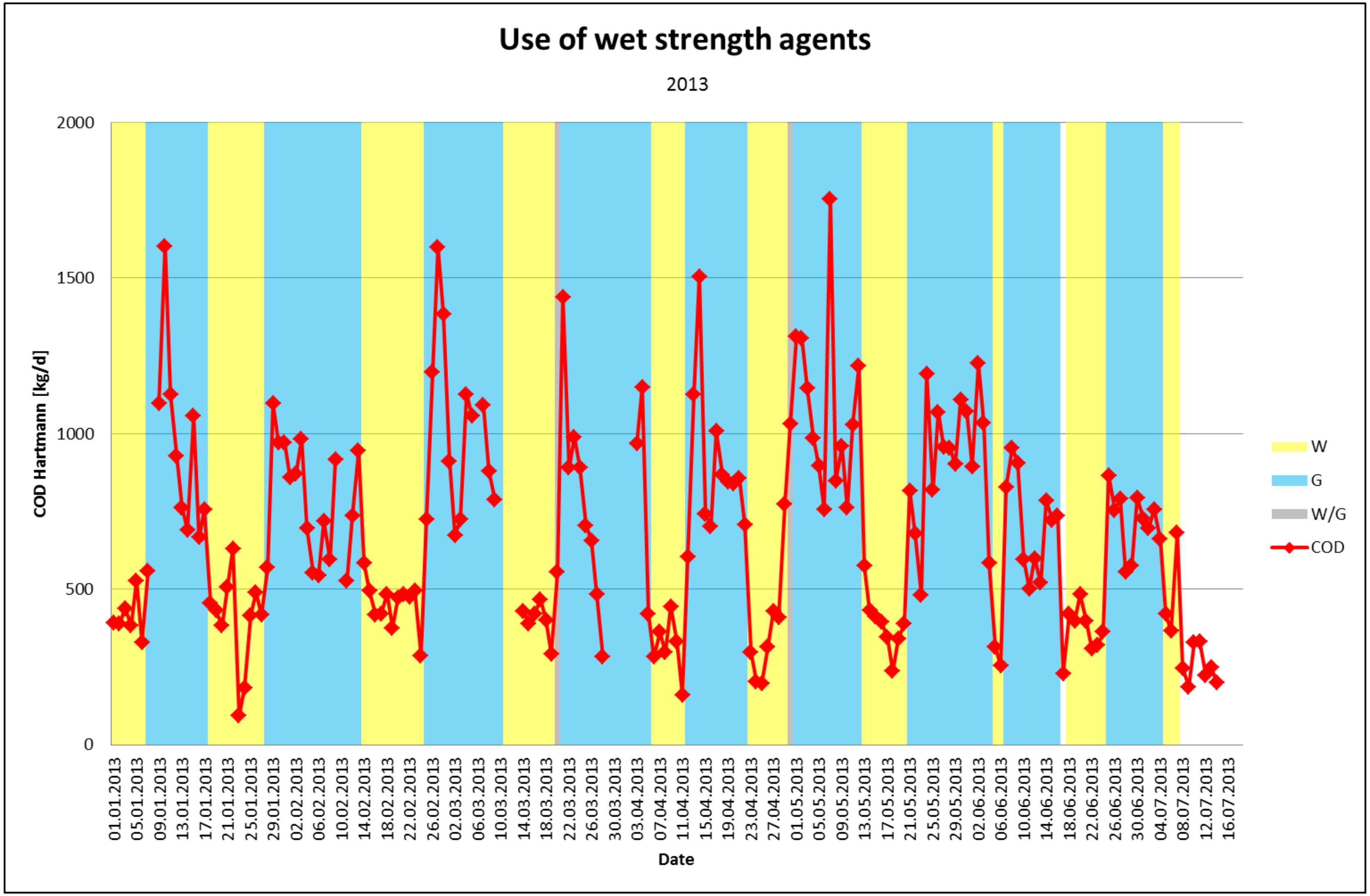
The process of the COD values of 2013 clearly shows that the COD loads are significantly higher when Giluton 20 XP (G, blue) is applied as if at the application of W (W, marked yellow) is applied. This is confirmed by the evaluation of the 85% percentiles which shows that there is on average an additional load of COD of approx. 638 kg COD/d when Giluton 20 XP is applied. This represents an increase of approx. 32%.

Table 7: 85 % percentile COD wet strength agent

85% percentile	COD [kg/d]
wet strength agent used	1122
no wet strength agent used	484

According to this result it can be assumed that the use of wet strength agents leads to an increase of the COD load in the effluent from the Paul Hartmann GmbH.

Figure 33: COD and use of wet strength agents in 2013



6 IMPACT ON THE LOCAL SEWAGE PLANT

6.1 Description of permission according to the water legislation assessment NKW2-WA-0477/002

The “Bezirkshauptmannschaft Neunkirchen” granted the Abwasserverband Grimmenstein-Edlitz-Thomasberg the permit according to the Water legislation for the amendment registered in the “Water Register” for the management district Neunkirchen under the ZIP code 4700 wastewater treatment plant by

- Operation of the wastewater treatment plant in accordance with a design capacity of 10.270 PE_{60} (organic load) and 14.000 PE_{200} (hydraulic load) with a max. inflow load of 616 kg organic BOD_5/d, and 2.800 m^3/d and
- Discharge of the treated wastewater into the recipient “Pitten” with a max. daily flow of 2.800 m^3/d treated wastewater at dry weather conditions
- 101.7 L/s or 366 m^3/d combined water in case of rainy weather according to the limits and minimum efficiencies throughout the annual average established under the in wastewater emission regulation for municipal wastewater, BGBl. II No. 210/1996 regulations regarding exceedance frequencies:
    - BOD_5 20 mg/L at 95 % efficiency
    - COD 75 mg/L at 85 % efficiency
    - NH_4-N 5 mg/L at temperature > 5° C
    - N_{total} 70 % efficiency at temperature > 12° C
    - P_{total} 7 mg/L

6.2 Facilities

WWTP characteristics are as follows:

- Measurement of inflow
- Operation building with implemented social rooms and SCADA, aerated sand and grease; blowers for selectors, aeration tanks and sand trap; mechanical excess sludge dewatering; sluge storage tank; conditioned high pressure sludge dewatering press (Pressmaster); installation for phosphate precipitation (dosing pumps and $FeCl_3$ storage tanks)
- 2 selectors with an correspondig volume of 103 m^3 and 309 m^3
- 2 aeration tanks each 1257 m^3

- Distribution structure with return sludge pumping station, scum pumping station and outflow weir
- 2 final sedimentation tanks each 1.100 m^3, $ø_i$ = 20 m
- Measurement of outflow amounts
- Roofed sludge storage area and for container handling.

The treatment of exceeding wastewater flow is performed by an existing storage tank as a part of the "old" wastewater treatment plant. Hereby the "old" secondary sedimentation tanks were reconstructed into a storm water treatment tank.

6.3 Original design values according to the Wasserrechtsbescheid

The WWTP Grimmenstein was constructed as part of the increase of the permission according to the water legislation, which was approved by the Bezirkshauptmannschaft Neunkirchen (NKW2-WA-0477/001, June 6th 2005) with the following parameters:

Q_d: 6.767 PE (municipal) x 0,2 m^3/r,d + 1.000 m^3/d (Hartmann) = 2.353 m^3/d + reserves = **2.400m^3/d**

BSB_5: 7.767 PE (municipal) x 0,06 kg/r,d + 172 kg/d (Hartmann) = **638 kg/d**

TKN: 7.767 PE (municipal) x 11 g/r,d + 0 kg/d (Hartmann) / 2.400 m^3 = **35,6 mg/L**

T_{SO}: 7.767 PE (municipal) x 70 g/r,d + 1.000 m^3/d x 15 mg/L (Hartmann) / 2.400 m^3 = **233 mg/L**

P: 7.767 EW (municipal) x 1,6 g/r,d + 0 (Hartmann) / 2.400 m^3 = **5,2 mg/L**

6.4 Project 2009

6.4.1 Occasion

Requested change of consensus for the wastewater of the Paul Hartmann GmbH in 2009:

- Raise of the wastewater amount from 1000 m^3/d to 1400 m^3/d
- Reduction of the wastewater loads from 172 kg BOD_5/d (2.866 PE_{60}) to 150 kg BOD_5/d (2500 PE_{60})

6.4.2 Purpose

It has to be evaluated by calculation of the aeration basin and the final sedimentation basin, if the increased amount of wastewater can be taken discharged into the sewage treatment plant by simultaneous reduction of the municipal wastewater loads.

6.4.2.1 Consensus values according to the approved "Project 1999"

	AWV	.Paul Hartmann GmbH
Wastewater amount Q_d	2.300 m^3/d	1.000 m^3/d
PE_{200} (hydr.)	11.500	5.196
PE_{60} (wastewater loads)	9.100	2.869
PE acc. statutes	1.0300	4.033

6.4.2.2 Change of consensus caused by the connection of the of the highway service area "Zöbern" 2005

Consensus values of Highway service area "Zöbern" 100 m^3/d and 1.500 PE_{60}

	AWV	Paul Hartmann GmbH
Wastewater amount Q_d	2.400 m^3/d	1.000 m^3/d
PE_{200} (hydr.)	12.000	5.196
PE_{60} (wastewater loads)	10.600	2.869
PE acc. statutes	11.300	4.033

6.4.2.3 Adjustment of the consensus values discharged into the municipal wastewater treatment plant by the Paul Hartmann GmbH

Wastewater flow and loads of Paul Hartmann GmbH acc. To existing project No. 2756 (IBL)

Daily amount of wastewater	1.400 m^3/d	=7.000 PE_{200}
BOD-load	150 kg/d	=2.500 PE_{60}
COD-load	400 kg/d	=3.330 PE_{120}

	AWV	**Paul Hartmann GmbH**
Wastewater amount Q_d	**2.800 m^3/d**	**1.400 m^3/d**
PE_{200} (hydr.)	**14.000**	**7.000**
PE_{60} (wastewater loads)	**12.230**	**2.500**
PE acc. statutes	**12.115**	**4.750**

6.4.3 Changed design values for consensus adjustment

The wastewater flow is raised from 1.000 m^3/d to 1.400 m^3/d and the wastewater loads will be reduced from 172 kg BOD_5/d (2.866 PE_{60}) to 150 kg BOD_5/d (2.500 PE_{60}), so the design values for the municipal wastewater treatment plant will be calculated as follows:

Q_d: 6.767 PE (municipal) x 0,2 $m^3/r,d$ + 1400 m^3/d (Hartmann) = 2.753 m^3/d + reserves = **2.800m^3/d**

BOD_5: 7.767 PE (municipal) x 0,06 kg/r,d + 150 kg/d (Hartmann) = **616 kg/d**

TKN: 7.767 PE (municipal) x 11 g/r,d + 0 kg/d (Hartmann) / 2.800 m^3 = **30,5 mg/L**

T_{SO}: 7.767 PE (municipal) x 70 g/r,d + 1.400 m^3/d x 15 mg/L (Hartmann) / 2.800 m^3 = **202 mg/L**

P: 7.767 PE (municipal) x 1,6 g/r,d + 0 (Hartmann) / 2.800 m^3 = **4,4 mg/L**

The calculated results in the project IBL (see table 10) represent too optimistic approaches for the parameters of the municipal wastewater treatment plant. Especially the calculation of the final sedimentation basin with an SVI of 100 ml/g

(Sludge volume index) and also the suspended solids content of 5 g/l in the aeration tank are way too optimistic.

It could be demonstrated by calculation, that the sewage plant fulfills the requirements of the ATV A 131 in terms of the IBL results, however it was only possible to meet these requirements by using very optimistic approaches. A thickening time of 2.97 h and 2.87 h was needed in the final clarification (the default of the ATV is 2.0 h and max. 2.5 h) to achieve the required suspended solids concentration in the aeration basin. In addition, a return sludge ratio of 1.0 from the final sedimentation basin was set (setpoint ATV 0.75). A summary of all calculated values is listed in table 10 in the annex.

6.4.4 Operating results 2012

From the existing operating protocols following values were evaluated for the change of the actual design:

Table 8: Amounts, wastewater loads and sludge index at the inflow of the WWTP Grimmenstein in 2012

	Inflow						AB 1		AB 2	
	Volume Q_{RW}	Volume Q_{TW}	BOD5	COD	NH4-N	P	ISV	DS	ISV	DS
		m³/d	kg/d	kg/d	kg/d	kg/d	ml/g	g/l	ml/g	g/l
Amount	91	267	40	96,00	96,00	96,00	154	156	11	11
Min	2.445	1.965	305	524	10	3		1,8	158	2,5
Max	16.688	5.917	933	3.721	88	36	393	4,3	370	3,8
Mean	**4.129**	**3.312**	**573**	**1.140**	**21**	**8**	**197**	**3,4**	**275**	**2,9**
Median	3.763	3.172	523	1.006	21	7	194	3,4	296	2,8
Standard dev.	1.685	686	175	495	8	5	56	0,5	69	0,4
AV+Std dev..	5.448	3.858	698	1.501	29	12	250	3,9	365	3,2
85% quantile	**5.267**	**3.972**	**792**	**1.581**	**26**	**11**	246	3,9	365	3,6

The converted values are the following:

Table 9: PE at the inflow of the WWTP Grimmenstein for the year 2012

	Inflow				
	Volume Q_{TW}	BOD5	COD	NH4-N	P
	PE200	PE60	PE120	PE7	PE1,8
Amount	267	40	96	96	96
Min	9.825	5.091	4.366	1.376	1.659
Max	29.585	15.551	31.012	12.635	19.933
Mean	**16.562**	**9.553**	**9.500**	**3.064**	**4.594**
Median	15.860	8.724	8.386	2.943	4.036
Standard dev.	3.428	2.910	4.124	1.176	2.672
AV+Stdabw.	19.288	11.634	12.510	4.118	6.708
85% quantile	**19.862**	**13.206**	**13.174**	**3.685**	**5.999**

6.4.5 Recalculation of the activated sludge plant

The activated sludge plant with a total volume of V = 2.514 m^3 and a surface of the final sedimentation tank of 624 m² was calculated according to ATV A131 with the program "Belebungsexpert V 2.01" with the revised design. The summary of the calculated results are listed in table 11 in the annex.

6.4.6 Results of the Recalculation

The recalculation was carried out for the design load (85% percentile).

The results show, that especially the high sludge volume index SVI of approx. 200 ml/g leads to problems in the final sedimentation tank.

A high sludge volume index indicates that in the sludge of the aeration tank filiform bacteria are present. This high sludge volume leads to poor sludge sedimentation and sludge overflow from the secondary clarifiers into the effluent.

The filiform bacteria indicate that there are easily degradable ingredients in the wastewater. This is typical for paper mill effluent, but also for septic wastewater due to high content of reduced sulfur. A combination of this usually means an enhancement of the bulking sludge tendency.

A high index also means that the suspended solids concentration in the aeration basin is way different from the selected theoretical approaches and the final sedimentation basin is actually much too shallow.

For aerobic sludge stabilization a sludge age of approx. 25 days is required. This requirement cannot be met with low suspended solids concentration in the aeration basin. The calculation resulted in a value from 12.7 to 13.7 days depending on the temperature (see table 11).

7 DISCUSSION

If the wastewater flow and loads produced by the Paul Hartmann GmbH and those from the municipal sewage plant Grimmenstein-Edlitz-Thomasberg are compared to each other, one can clearly see that there is an influence from the wastewater of the Paul Hartmann GmbH. In the time course of 2010-2011 a continuous increase in the discharged wastewater flow and loads can be determined. Furthermore the effect of the application of wet strength agents represented an additional COD load of approx. 32% in 2013.

Since neither a direct nor an indirect correlation of the COD in the filtrate of the belt filter press and the COD in the sediment could be detected, it is very likely that filtrate wastewater from the belt filter press has no significant effect on the periodically increased loads.

The comparison via regression analysis of the individual values of the outflow from the Paul Hartmann GmbH and the individual values of the inflow to the municipal sewage treatment plant shows that the influence of the wastewater flow and loads discharged from the company Paul Hartmann GmbH have no relation to the inflow loads to the municipal wastewater treatment plant. A possible cause for these wastewater peak flows and loads could be the nearby highway service area, but there is no data available to confirm this.

However, it must be noted that in the diagrams of the regression analysis individual values are shown while the curves of the time series represent the 14-day averages. Also the manner and timing of the sample collection and analysis have great influence on the measured values. For a more accurate assessment, frequent and coordinated measurements of the wastewater loads would be necessary. Especially from the municipal sewage treatment plant there are partially very few values compared to the Paul Hartmann GmbH available.

The results of the IBL project in 2009 were statistically analyzed and compared with the values of the statistical evaluation of 2012. It is particularly striking that the sludge volume index (SVI) in the municipal wastewater treatment plant is 100% higher than the sludge volume index assumed in the calculation of the consultant IBL in 2009. Also the suspended solids concentration in the aeration tank is actually only approx. 2.9 to 3.4 g/L instead of 5g/L.

This means that the final sedimentation tank actually is much too shallow despite the very low surface load and that there is not enough time for the sludge to settle.

Bulking sludge (ISV> 150 mL/g) occurs especially for easily degradable and nutrient-poor effluents of the paper industry. It can also occur in connection with the treatment of highly concentrated organic, septic wastewater as obtained from the highway service area.

After the evaluation of the existing data there are two possible options to be considered.

The first option is to adjust the municipal wastewater treatment plant of the AWV Grimmenstein-Edlitz-Thomasberg through extension of the assessment, extension of the final sedimentation and establishment of external sludge stabilization.

The second option is to establish a biological pretreatment facility for the wastewater from the Paul Hartmann GmbH to eliminate easily degradable wastewater compounds.

Moreover it is recommended to perform a detailed investigation in terms of flows and loads for the wastewater from the highway service area, especially in terms of shock loads and H_2S content.

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9 ANNEX

Table 10: Values acc. to ATV 131 in 2000

ARA Grimmenstein

(Eingabewerte lt. ATV 131, Mai 2000)

				2 Rundbecken; lt. WRB Auslegung mit TS $_{BB=5,0}$	2 Rundbecken; Änderung Auslegung mit TS $_{BB=4,97}$
	1	2	3	4	5
1	Nachklärbecken		Dimension	**Qm**	**Qm**
2	**Mischwasserzufluß**	Q_m	l/s	**100,50**	**101,70**
3	Mischwasserzufluß	Q_m	m^3/h	361,8	366,1
4	**Trockensubstanzgehalt**	TS_{BB}	g/l	**5,00**	**4,97**
5	**Schlammindex**	ISV	ml/g	**100**	**100**
6	Schlammvolumenbeschickung	q_{sv}	$l/(m^2xh)$	288,06	289,75
7	Flächenbeschickung	q_A	m/h	0,58	0,58
8	**Beckenoberfläche**	A_{NB}	m^2	**628**	**628**
9	Durchmesser			19,99	19,99
10	**Eindickzeit**	t_E	h	**2,91**	**2,87**
11	Trockensubstanzgehalt Beckensohle	TS_{BS}	g/l	14,28	14,21
12	Trockensubstanzgehalt Rücklaufs.	TS_{RS}	g/l	9,99	9,95
13	**Rücklaufverhältnis**	RV		**1,00**	**1,00**
14	Trockensubstanzgehalt BB	TS_{BB}	g/l	5,00	4,97
15	**Klarwasserzone (min. 0,5m)**	h1	m	**0,50**	**0,50**
16	Trennzone	h2	m	1,15	1,16
17	Speicherzone	h3	m	0,52	0,52
18	Eindickzone	h4	m	1,17	1,17
19	Gesamthöhe	h_{ges}	m	3,35	3,35
20		Q_{rs}	m^3/h	361,80	366,12
21		V	m^3	2100,67	2104,36
22		t	h	5,81	5,75
23		h_{gew}	m	**3,50**	**3,50**
24		V_{vorh}	m^3	2198,00	2198,00
25		t_{vorh}	h	6,08	6,00

Table 11: Summary of the results of the calculations

Projekt: ARA Grimmenstein

bearbeitet von: berechnet am: 03.02.2014

Zusammenfassung der Ergebnisse

ANLAGENKONFIGURATION:

- Aerober Selektor
- Belebungsbecken
- Nachklärung

REINIGUNGSZIELE:

- Abbau des org. Kohlenstoffs
- Nitrifikation
- Denitrifikation
- Phosphor-Simultanfällung

Denitrifikationsverfahren: Simultane Denitrifikation
Fällmittel: Dreiwertiges Eisen
Nachklärung: Beckentyp Rundbecken, Strömung horizontal, Schildräumer

LASTANNAHMEN:

Größenklasse: 734 kg BSB_5/d

Berechnete Lastfälle:

- Lastfall 1: Bemessung
- Lastfall 2: Nachweis der Nitrifikation bei tiefster Temperatur
- Lastfall 3: Ermittlung des Sauerstoffbedarfs bei höchster Temperatur

Berechnung auf BSB -Basis

	Lastfall	1	2	3
Zulaufmenge:				
Abwassermenge	Q_d	3973	3973	3973 m³/d
	Q_t	200	200	200 m³/h
Zulauffrachten:				
CSB	$B_{d,CSB}$	1581	1581	1581 kg/d
Gelöster CSB	$B_{d,SCSB}$	0	0	0 kg/d
BSB_5	$B_{d,BSB}$	792	792	792 kg/d
Verhältnis CSB/BSB_5	-	2,00	2,00	2,00 -
Abfiltrierbare Stoffe	$B_{d,XTS}$	600	600	600 kg/d
Kjeldahl-Stickstoff	$B_{d,TKN}$	68,7	68,7	68,7 kg/d
Ammoniumstickstoff	$B_{d,NH4}$	25,0	25,0	25,0 kg/d
Nitratstickstoff	$B_{d,NO3}$	0,0	0,0	0,0 kg/d
Phosphor	$B_{d,P}$	10,8	10,8	10,8 kg/d
Säurekapazität	S_{KS}	5,00	5,00	5,00 mmol/l

ABLAUFKONZENTRATIONEN:

Ammoniumstickstoff	$S_{NH4,AN}$	1,0	1,0	1,0 mg/l
Nitratstickstoff	$S_{NO3,AN}$	4,3	4,3	0,0 mg/l
Phosphor	$S_{P,AN}$	0,7	0,7	0,7 mg/l
Säurekapazität	$S_{KS,AN}$	4,3	4,3	4,6 mmol/l

BETRIEBSDATEN:				
in Biomasse eingebundener Stickstoff	$X_{N,BM}$	10,0	10,0	10,0 mg/l
nitrifizierter Stickstoff	$S_{NH4,N}$	4,3	4,3	4,3 mg/l
denitrifiziertes Nitrat	$S_{NO3,D}$	0,0	0,0	4,3 mg/l
in Biomasse eingebundener Phosphor	$X_{P,BM}+X_{P,BIOP}$	2,0	2,0	2,0 mg/l
gefällter Phosphor	$X_{P,Fäll}$	0,0	0,0	0,0 mg/l
Fällmittelbedarf	FM	0,0	0,0	0,0 kg Metall/d

BELEBUNGSBECKEN:				
Volumen Belebungsbecken	V_{BB}	2514	2514	2514 m³
erforderlicher Sicherheitsfaktor	erf. SF	1,80	1,20	1,80 -
vorhandener Sicherheitsfaktor	vorh. SF	4,45	2,28	5,59 -
Denitrifikationsanteil	V_D/V	0	0	10 %
Temperatur	T	16,00	10,00	19,00 °C
Schlammtrockensubstanz	TS_{BB}	3,36	3,36	3,36 kg/m³
Schlammalter	t_{TS}	13,7	12,7	14,3 d
aerobes Schlammalter	$t_{TS,aer.}$	13,7	12,7	12,8 d
Schlammproduktion:				
Tägliche Schlammproduktion	UES_d	614	667	592 kg/d
... davon aus P-Elimination	$UES_{d,P}$	0	0	0 kg/d
... davon aus ext. C-Dosierung	$UES_{d,ext}$	0	0	0 kg/d
Sauerstoffverbrauch:				
... aus C-Abbau	$OV_{d,C}$	943	865	976 kg/d
... aus Nitrifikation	$OV_{d,N}$	74	74	74 kg/d
... aus Denitrifikation	$OV_{d,D}$	0	0	-50 kg/d
Täglicher Sauerstoffverbrauch	OV_d	1017	939	1000 kg/d
Mittlerer stündl. Sauerstoffverbrauch	OV_h	42,4	39,1	41,7 kg/h
Stoßfaktor C	f_C	1,15	1,15	1,15 -
Stoßfaktor N	f_N	2,00	2,00	2,00 -
Maximaler stündl. Sauerstoffverbrauch	OV_h	48,3	44,5	47,5 kg/h
Erforderl. stündl. Sauerstoffeintrag	$alpha*OC_h$	60,5	54,1	60,5 kg/h

Projekt: ARA Grimmenstein

bearbeitet von: berechnet am: 03.02.2014

Zusammenfassung der Ergebnisse (Nachklärung)

Allgemeines, Wassermenge		
Beckentyp: Rundbecken		
Art der Durchströmung: horizontal		
Räumertyp: Schildräumer		
Maßgebende Wassermenge	Q_m	253 m^3/h
Schlammindex, Eindickzeit, Rücklaufverhältnis:		
Schlammindex, gewählt	ISV	200 l/kg
Eindickzeit des Schlammes, gewählt	tE	3,0 h
Rücklaufverhältnis bei RW, gewählt	RV	2,00
Schlammtrockensubstanz im Rücklaufschlamm	TS_{RS}	5,0 kg/m^3
Zulässige Schlammtrockensubstanz im Ablauf Belebungsbecken	TS_{AB}	3,37 kg/m^3
Gewählte Schlammtrockensubstanz im Ablauf Belebungsbecken	TS_{AB}	3,36 kg/m^3
Beckenoberfläche, Anzahl und Abmessungen:		
Zulässige Schlammvolumenbeschickung	qSV	500 $l/(m^2*h)$
Zulässige Flächenbeschickung	qA	1,60 m/h
Erf. Gesamt-Beckenoberfläche	A_{NB}	340 m^2
Anzahl der Becken	a	2
Erforderlicher Durchmesser	D_{NB}	14,71 m
Gewählter Durchmesser	D_{NB}	20,00 m
Durchmesser des Mittelbauwerks	D_{MB}	2,40 m
Vorhandene Beckenoberfläche	A_{NB}	628 m^2
Vorhandene Schlammvolumenbeschickung	qSV	271 $l/(m^2*h)$
Vorhandene Flächenbeschickung	qA	0,40 m/h
Beckentiefe:		
Klarwasserzone	h_1	-0,89 m
Trenn- und Rückströmzone	h_2	1,84 m
Dichtestrom- und Speicherzone	h_3	0,73 m
Eindick- und Räumzone	h_4	1,69 m
Maßgebende Beckentiefe	h_{ges}	3,37 m
Tiefe des Einlaufs unter WSP	h_e	1,90 m
Räumer:		
Räumschildhöhe	h_{SR}	0,40 m
Anzahl der Räumerarme	a_r	1,0 -
Räumgeschwindigkeit	v_{SR}	140 m/h
Räumfaktor	f_{SR}	1,40 -
Räumintervall	t_{SR}	0,45 h
Erforderlicher Räumvolumenstrom	Q_{SR}	305 m^3/h
Vorhandener Räumvolumenstrom	Q_{SR}	400 m^3/h

Die Schlammbilanz ist erfüllt.