

CONDUCTIVITY MEASUREMENTS FOR CONTROLLING MUNICIPAL WASTE-WATER TREATMENT

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Abstract Conductivity measurements can be used to monitor the processes in wastewater treatment that causes changes in conductivity. The processes that in many treatment plants cause changes in conductivity are mainly biological nitrogen removal. Conductivity measurements from two WWTP in Stockholm show no reduction of conductivity in the presedimentation and 21 and 28% reduction in the activated sludge process. The conductivity in the inflowing wastewater to Lotsbroverket WWTP in Mariehamn, Åland, during 2006 varies from 58 mS/m to 137 mS/m with about 23% reduction of conductivity in the activated sludge process. At Duvbacken WWTP in Gävle, which have biological phosphorus removal and no nitrogen removal, the conductivity varied between 60 and 100 mS/m with no difference between influent and effluent. Biological P-removal will give a reduction with 344 to 278 $\mu\text{Sm}^2/\text{g P}$. However, since the contribution of phosphate ions can be calculated to about 1 % of measured conductivity phosphorus removal will not give any decrease in conductivity. Since ammonium nitrogen and alkalinity, which is reduced at biological nitrogen removal, contributes to conductivity with about 33 % and 14 % respectively, it is the three WWTP with biological nitrogen removal that has a decrease in conductivity in the treatment process. At chemical phosphorus precipitation phosphate will substituted with sulfate and no reduction in conductivity will be achieved. Reduction of conductivity due to biological nitrogen removal will consume alkalinity or hydroxide ions. If the amount of available alkalinity is high enough (one mole alkalinity per mole ammonia) biological N-removal through nitrification followed by denitrification will give a decrease of conductivity with 842 $\mu\text{Sm}^2/\text{g N}$. Separation processes such as removal of suspended solids through sedimentation or filtration will give no changes ion conductivity. Separation of nutrients through reverse osmosis will give large changes in conductivity and conductivity can thus be used for controlling the process.

Keywords Conductivity, Wastewater treatment, Phosphate, Nitrate, Biological nutrient removal.

INTRODUCTION

Conductivity is a parameter which is simple to measure and can easily be measured with continuous measurement device. This parameter is a general indicator of water quality, especially a function of the amount of dissolved salt, and can be used to monitor processes in the wastewater treatment that causes changes in total salt concentration and thus changes the conductivity. The salt content can be determined by analyzing samples in laboratory. However, using laboratory analyzing the analyze result will available with a delay which makes it less useful for controlling the treatment process. Conductivity can be measured directly in the process and give values can be obtained directly and therefore can be used to monitor and control the process. Chemical analyzing can be made on line with electrodes or computerized analyzing devices. The cost for this is however high, which can make on line conductivity measuring an interesting alternative. This work will try to identify where in the treatment process conductivity can be used to monitor and thereby control the process.

Many municipalities requires that industries and similar enterprises which discharges sewage to the wastewater net, measure conductivity and that it is not allowed to be higher than 500 mS/m (Eskilstuna et al, 2002, Hellström et al, 2001). To high conductivity causes corrosion problem in the sewage pipe network. Otherwise conductivity measurement in not so much used in the wastewater treatment.

The variation of conductivity in the wastewater can be caused by variation of the ion content. Ions that cause conductivity are hydrogen H^+ , hydroxide OH^- and nutrients such as phosphate and nitrate. The hydrogen and hydroxide ion contribution to conductivity is a function of pH:

$$[H^+] = 10^{(-pH)} \text{ mol/liter} = 10^{(-pH+3)} \text{ mole/m}^3 = 10^{(-pH+3)} \text{ g/m}^3$$

$$[OH^-] = 10^{(pH-14)} \text{ mol/liter} = 10^{(pH-11)} \text{ mol/m}^3 = 10^{(pH-11)}/17 \text{ g/m}^3$$

For H^+ the molar conductivity per concentration unit is $350 \cdot 10^{-4} \text{ Sm}^2/\text{mol}$ (CRC Handbook, 1999):

$$K_H = 10^{(-pH+3)} \text{ mol/m}^3 \times 350 \cdot 10^{-4} \text{ Sm}^2/\text{mol} = 35 \cdot 10^{(-pH)} \text{ S/m}$$

For OH^- the molar conductivity per concentration unit is $198 \cdot 10^{-4} \text{ Sm}^2/\text{mol}$ (CRC Handbook, 1999):

$$K_{OH} = 10^{(pH-11)} \text{ mol/m}^3 \times 198 \cdot 10^{-4} \text{ Sm}^2/\text{mol} = 198 \cdot 10^{(pH-15)} \text{ S/m} = 1.98 \cdot 10^{(pH-7)} \mu\text{S/m}$$

Phosphate ion contribution to conductivity depends on pH-level. For $pH > 2.15$ and < 7.20 the phosphate ion is $H_2PO_4^-$, the molar conductivity per concentration unit is $3.3 \text{ mSm}^2/\text{mol}$ (CRC Handbook, 1999) and the conductivity is:

$$K_{H_2PO_4^-} = \frac{C_P \text{ g P/m}^3 \times 33 \cdot 10^{-4} \text{ Sm}^2/\text{mole}}{31 \text{ g/mole}} = C_P \times 107 \mu\text{S/m}$$

if the concentration C_P is given in mg $PO_4\text{-P}$ /liter (1mg/liter=1g/m³).

For $pH > 7.20$ and < 12.02 phosphate ion is HPO_4^{2-} , the molar conductivity per concentration unit is $3.3 \text{ mSm}^2/\text{mol}$ (CRC Handbook, 1999) and the conductivity is:

$$K_{HPO_4^{2-}} = \frac{C_P \text{ g P/m}^3 \times 66 \cdot 10^{-4} \text{ Sm}^2/\text{mole}}{31 \text{ g/mole}} = C_P \times 213 \mu\text{S/m}$$

if the concentration C_P is given in mg $PO_4\text{-P}$ /liter (1mg/liter=1g/m³).

At $pH=7.2$ some phosphate ions are $H_2PO_4^-$ and other are HPO_4^{2-} , which gives that the conductivity depends on pH. An increase of pH gives that conductivity increases from a low level of $107 \times C_P \mu\text{S/m}$ below $pH=7.2$ to a high level of $213 \times C_P \mu\text{S/m}$ above $pH = 7.2$.

CONDUCTIVITY CHANGES THROUGH BIOLOGICAL PHOSPHORUS REMOVAL

The main processes that reduces conductivity in wastewater treatment are biological nutrient removal. Conductivity measurement can be used for control of a sequential batch process SBR for biological phosphorus removal (Aguado et al. 2006, Maurer och Gujer, 1995). At biological phosphorus removal the activated sludge must be exposed to two alternating conditions; an anaerobic (neither oxygen nor nitrate) environment with readily biodegradable substrate and an aerobic. In an sequential process this is made in two phases. In the first phase, the sludge release phosphate and the concentration of dissolved phosphorus increases while the soluble COD

decreases. Figure 1 shows a sketch of the biological phosphorus removal mechanism for phosphate accumulating microorganisms. During the aerobic phase, the sludge takes up phosphate and the concentration of dissolved phosphorus decreases, normally to a lower value than at the beginning of the cycle. Together with phosphate the sludge releases and takes up counter ions such as K, potassium and Mg, magnesium. On-line monitoring of the phosphorus-concentration is, in such mostly small systems, usually not possible. However, by measuring conductivity the release shown as an increase in conductivity and the up take as a decrease. Figure 2 shows how conductivity and phosphate concentration first increases in the anaerobic phase and thereafter decrease in the aerobic phase. By following the conductivity variations it will be possible to decide when the sludge during the anaerobic phase has released maximum phosphate, which is shown by the end of increase of conductivity. The process can when be converted to the aerobic phase, which can be ended when the sludge has taken up maximum phosphate and the conductivity decrease is ends. The changes in conductivity can be calculated from the molar conductivity per concentration unit, which is 3.3 mSm^2/mol for H_2PO_4^- , 7.348 for K^+ mSm^2/mol and 10.6 mSm^2/mol for Mg^{2+} (CRC Handbook, 1999). If conductivity only is calculated on phosphate ions, the co variation between phosphate and conductivity will be 107 $\mu\text{Sm}^2/\text{g P}$ (3.3 mSm^2/mol). If release/up take is one mole potassium per mole phosphate the co variation will be 344 $\mu\text{Sm}^2/\text{g P}$ (10.6 mSm^2/mol). An release/up take of a half mole magnesium per mol phosphate gives a co variation of 278 $\mu\text{Sm}^2/\text{g P}$ (8.6 mSm^2/mol). If both potassium and magnesium are released/taken up together with phosphate there will be a co variation between 344 and 278 $\mu\text{Sm}^2/\text{g P}$ depending on the amount of magnesium and potassium.

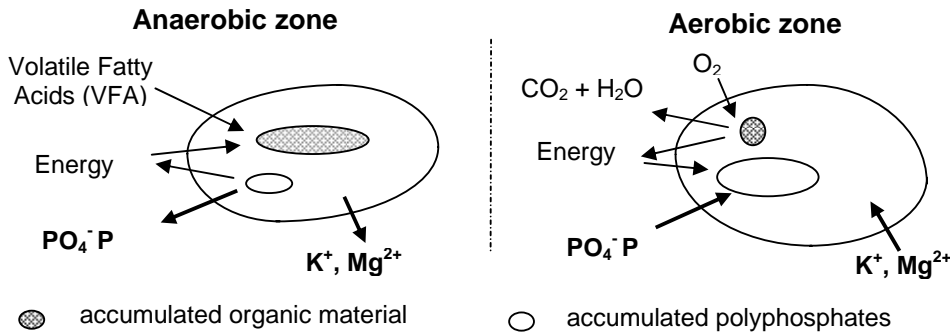


Figure 1. Biological phosphorus removal mechanism for phosphate accumulating microorganisms.

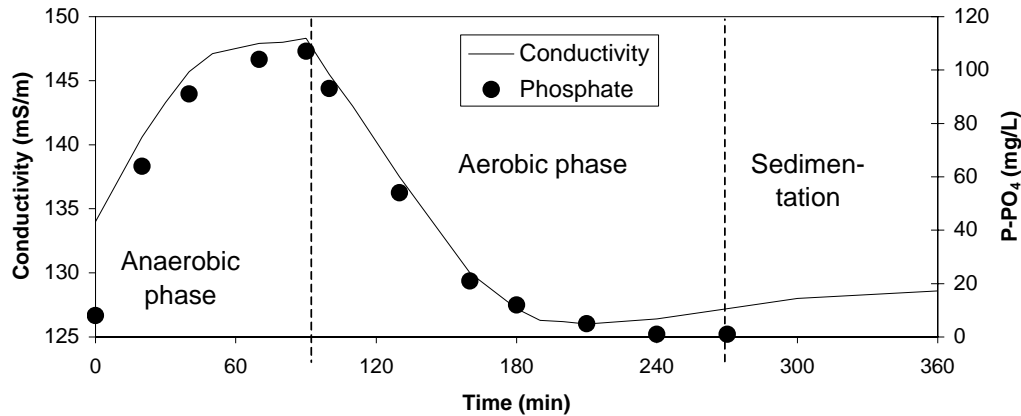


Figure 2. Changes of conductivity and phosphate content at a sequential batch process SBR for biological phosphorus removal (Barat et al., 2005).

CONDUCTIVITY CHANGES THROUGH BIOLOGICAL NITROGEN REMOVAL

Table 1 shows changes in conductivity at biological nitrogen removal through nitrification and denitrification with either hydrogen ion production or alkalinity consumption. Since ammonium, nitrite and nitrate has almost the same molar conductivity, the transformation of ammonium to nitrite or nitrate gives a change in conductivity which depends on which other ions that are produced or consumed. If the transformation consumes hydroxide or alkalinity the conductivity decreases. However, if the transformation produces hydrogen ions the conductivity increases. If the amount of alkalinity is large enough the nitrogen transformation at for instance nitrification will reduce the conductivity continuously, and conductivity measuring can be used to control the nitrification. However, if the amount of alkalinity is too small the conductivity will first decrease and thereafter increase again when the alkalinity is consumed and further nitrification produces hydrogen ions. For nitrification of all ammonia produced at for instance anaerobic digestion two dihydrogen carbonate ions is consumed per ammonia, which is twice the amount of alkalinity produced at the digestion. However, hydrogen ions produced at the following denitrification step will be consumed again and the net consumption of will be one dihydrogen carbonate ion per ammonia ion. This will give a total decrease of conductivity with $842 \mu\text{Sm}^2/\text{g N}$ ($11.79 \text{ mSm}^2/\text{mol N}$).

In sewage water is the content of alkalinity mostly more than the content of ammonium, and nitrification can therefore occur without hydrogen ion production. In an activated sludge process with biological nitrogen removal the denitrification is often made in an anoxic step before nitrification which is made in a thereafter following aerobic step. The sludge is recirculated from nitrification to denitrification. Alkalinity produced at denitrification can thereby be added to alkalinity in the incoming sewage.

Table 1. Conductivity changes at biological nitrogen removal through nitrification and denitrification with (A) hydrogen ion production and (B) alkalinity consumption.

A	Reaction	Change in ion content	$\frac{\text{mSm}^2}{\text{mol N}}$	$\frac{\text{mSm}^2}{\text{g N}}$
Nitrification	$\text{NH}_4^+ + 2\text{O}_2 \rightarrow$	-1 NH_4^+	-7.34	-0.524
	$\text{NO}_3^- + 2\text{H}^+ + \text{H}_2\text{O}$	+1 NO_3^-	7.14	0.510
		+2 H^+	70.00	4.998
			69.80	4.983
Denitrification	$\text{NO}_3^- + \frac{5}{6}\text{CH}_3\text{OH} + \text{H}^+ \rightarrow$	-1 NO_3^-	-7.14	-0.510
	$\frac{1}{2}\text{N}_2 + \frac{5}{6}\text{CO}_2 + 2\frac{1}{6}\text{H}_2\text{O}$	-1 H^+	-35.00	-2.499
			-42.14	-3.009
Nitrification + Denitrification			27.66	1.975

B	Reaction	Change in ion content	$\frac{\text{mSm}^2}{\text{mol N}}$	$\frac{\text{mSm}^2}{\text{g N}}$
Nitrification	$\text{NH}_4^+ + 2\text{O}_2 + 2\text{HCO}_3^- \rightarrow$	-1 NH_4^+	-7.34	-0.524
	$\text{NO}_3^- + 3\text{H}_2\text{O} + 2\text{CO}_2$	+1 NO_3^-	7.14	0.510
		-2 HCO_3^-	-8.90	-0.635
			-9.10	-0.650
Denitrification	$\text{NO}_3^- + \frac{5}{6}\text{CH}_3\text{OH} +$	-1 NO_3^-	-7.14	-0.510
	$\frac{1}{6}\text{CO}_2 \rightarrow \frac{1}{2}\text{N}_2 +$	+1 HCO_3^-	4.45	0.318
	$1\frac{1}{6}\text{H}_2\text{O} + \text{HCO}_3^-$		-2.69	-0.192
Nitrification + Denitrification			-11.59	-0.842

Molar conductivity per concentration unit (CRC Handbook, 1999): NH_4^+ 7.34, NO_3^- 7.14, H^+ 35 and HCO_3^- 4.45 (mSm^2/mol).

CONDUCTIVITY MEASURED IN THE TREATMENT PROCESS

Figure 3 shows conductivity measured from January 2006 at three points; inlet, outlet and at presedimentation, at Lotsbroverket WWTP in Mariehamn, Finland (Fagerström, 2006). Figure 4 shows a sketch of the treatment process. The conductivity were almost the same in the inlet and at presedimentation and lower after the activated sludge process at the outlet from the plant. The diagram shows also the reduction in conductivity between inlet and outlet. The difference in conductivity in the inlet varies from 58 mS/m in April to 137 mS/m in July. This can be caused diluting the wastewater by snow melting in spring.

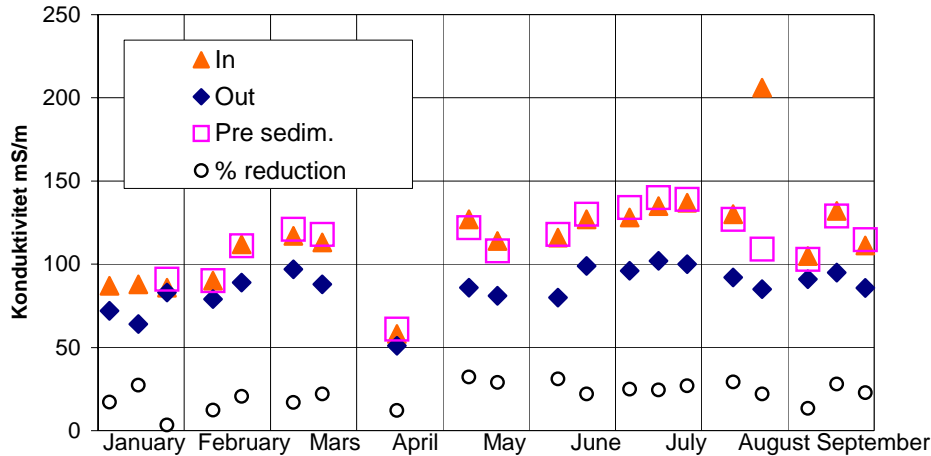


Figure 3. Conductivity variation during year 2006 at Lotsbroverket WWTP, Mariehamn Åland, and per cent reduction of conductivity in the sewage treatment process (Levlin and Hultman, 2008).

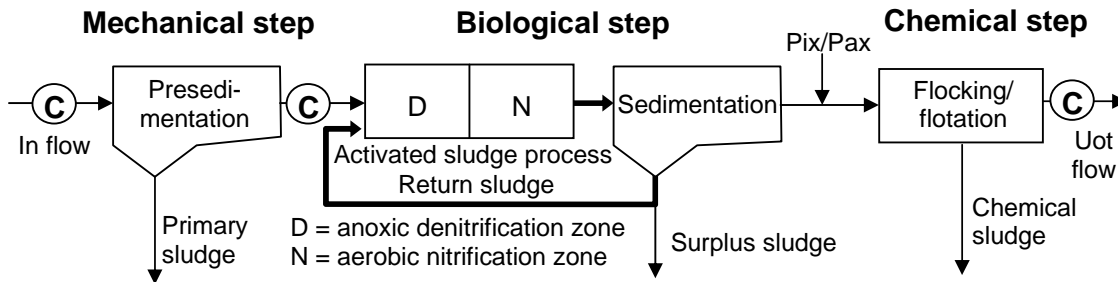


Figure 4. Sketch of Lotsbroverket treatment plant with three treatment step; mechanical, biological and chemical treatment, and the three points for conductivity measurement (C) (Levlin and Hultman, 2008).

Figure 5 shows conductivity variation during year 2005 to 2007 at Duvbacken WWTP, Gävle, in incoming sewer and outgoing treated effluent (Eklund, 2007). At Duvbacken, which have biological phosphorus removal and no nitrogen removal, the conductivity varied between 60 and 100 mS/m with no difference between influent and effluent.

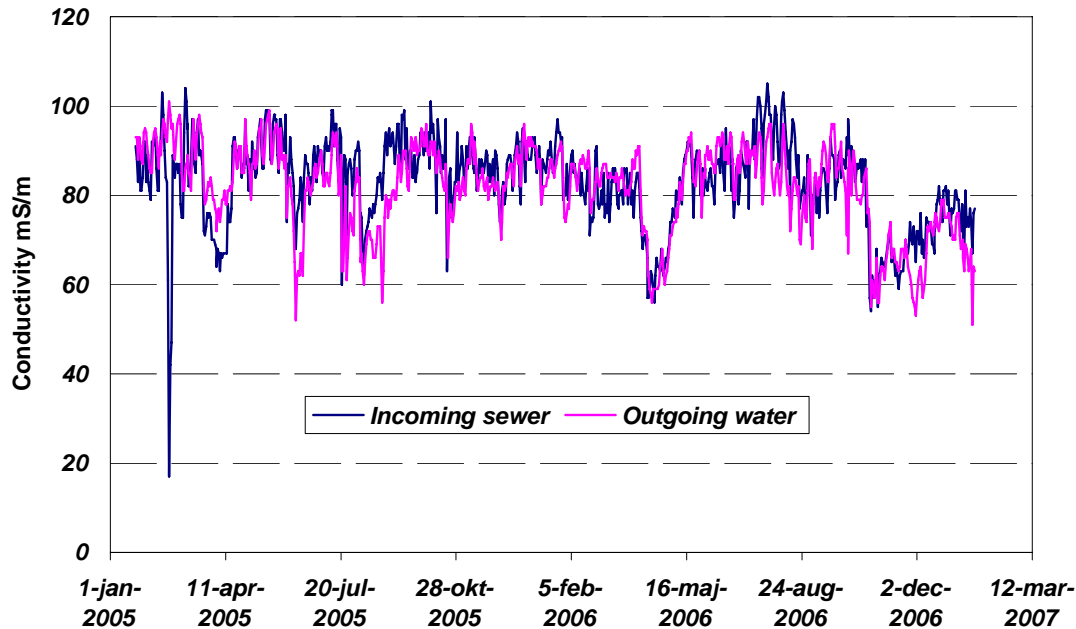


Figure 5. Conductivity variation during year 2005 to 2007 at Duvbacken WWTP, Gävle, in incoming sewer and outgoing treated effluent (Levlin and Hultman, 2008).

These measured conductivity values can be compared to conductivity values measured at two WWTP in the Stockholm region; Käppalaverket, Lidingö and Himmerfjärdsverket, Botkyrka (Levlin and Hultman, 2008). Both Käppalaverket and Himmerfjärdsverket have biological nitrogen removal with sand filter as a final treatment step. In Käppalaverket nitrification and denitrification is made in the activated sludge process while in Himmerfjärdsverket nitrification is made in the activated sludge process while denitrification is made in a fluidized bed following post sedimentation. For phosphorus removal in Käppalaverket, part of the wastewater is treated in the old lines through biological phosphorus removal and the rest in the new lines through chemical precipitation in the return sludge. In Himmerfjärdsverket phosphorus removal is made through chemical precipitation at presedimentation. The conductivity in the influent was 106 mS/m for Käppala and 79 mS/m for Himmerfjärden. A large increase of conductivity was achieved at sludge digestion. The highest conductivity values were achieved in the digestion chambers; 797 mS/m for Käppala and 656 mS/m for Himmerfjärden. The large conductivity increase at digestion shows that conductivity measurements can be a useful method to control the digestion process. The difference between Käppalaverket and Himmerfjärdsverket can be explained by variation of conductivity with time in the inflowing wastewater between the day when the measurements were made at Käppalaverket and the day when the measurements were made at Himmerfjärdsverket. Table 2 shows a comparison of conductivity measured at the four WWTP (Levlin and Hultman, 2008).

Table 2. Comparison of conductivity measured at four WWTP (Levlin and Hultman, 2008).

	Käppalaverket Lidingö	Himmerfjärds- verket Botkyrka	Duvbackens reningsverk Gävle	Lotsbroverket Mariehamn, Åland
Capacity	530 000 PE	310 000 PE	100 000 PE	30 000 PE
P-removal	Old: Biolo- gical	New: Chemical in return sludge	Chemical precipitation at presedimentation	Biological Chemical flocking and flotation after activ. sludge proc.
N-removal			No removal	
Nitrification:	Activ. sludge proc.	Activ. sludge proc.		Activ. sludge proc.
Denitrification	Activ. sludge proc.	Fluidized bed		Activ. sludge proc.
In flow	Old: 103.4 New: 105.9	78.8	82.9	111 Sort mS/m
Presedimentation	103.4	109.4	71.0	115 mS/m
After activ. sludge	76.1	77.3	63.8	mS/m
After Fluidized bed			61.1	mS/m
Outflow	76.6	62.2	81.6	86 mS/m
Reduction	28	21	1.6	23 %

Many parameters have been analyzed of sewage water at Hammarby Sjöstad, Stockholm, including conductivity (Magnusson, 2003). From the analyses the contribution of phosphate ions can be calculated to about 1 % of measured conductivity. Ammonium nitrogen and alkalinity, which is reduced at biological nitrogen removal, contributes to conductivity with 33 % and 14 % respectively. Since the alkalinity is more than one mole per mole ammonium, biological nitrogen removal through nitrification followed by denitrification will give a decrease of conductivity with 842 $\mu\text{Sm}^2/\text{g N}$. As the conductivity measurements at the four WWTP shows, it is the plant with biological nitrogen removal that has a decrease in conductivity in the treatment process.

Table 3 shows wastewater concentration at inlet, after presedimentation and at outlet at two WWTP in Granada, Spain (Howard et al., 2004). The conductivity in this case is almost the same in inlet and outlet. In the activated sludge process mainly biological bound nutrients there removed and the nitrite content increased while the phosphate content decreased. There was no net change in the ion content and the conductivity remained the same through the process. There was only a small reduction of ammonium and phosphate was reduced with 5,6 mg/L, which gives a reduction in conductivity of 0.39 mS/m. This is small compared to the total conductivity of 90 mS/m. Removal of all dissolved phosphate had decreased conductivity with 2.3 mS/m (33.8×0.069) and all ammonium had decreased conductivity with 21.6 mS/m ($53 \times 7,35/18$).

Table 3. Wastewater concentration and conductivity at inlet, presedimentation and at outlet at two WWTP in Granada, Spain (Howard et al., 2004).

	Inflow	Stand. dev.	After pre-sediment.	Stand. dev.	Out-flow	Stand. dev.	Reduction
BOD ₅ (mg/L)	317.4	97.6	274.9	92.6	75.0	67.1	76.4 %
COD (mg/L)	778.4	210.5	517.5	82.0	184.2	142.0	76.6 %
Conductivity (mS/m)	96.22	20.7	92.65	11.4	91.96	11.4	4.4 %
TS (mg/L)	873.9	282.3	602.1	182.8	606.1	235.6	30.6 %
Ammonia (mg/L)	53.0	15.4	59.0	20.1	51.8	17.9	2.3 %
Nitrate (mg/L)	6.0	5.0	4.9	3.7	6.2	5.3	-3.3 %
Nitrite (mg/L)	0.2	0.1	0.4	0.4	1.9	1.9	-850 %
Total-N (mg/L)	185.8	107.7	166.9	91.6	130.1	84.8	30.0 %
Phosphate (mg/L)	33.8	10.7	33.8	11.3	28.2	9.8	16.6 %
Total-P (mg/L)	45.6	30.6	41.7	34.6	33.7	23.6	26.1 %
Fat (mg/L)	105.3	59.1	78.3	54.6	32.5	36.1	69.1 %
Dissolved protein (mg/L)	60.1	21.1	50.5	11.6	24.1	11.1	59.9 %
Total protein (mg/L)	112.5	31.2	72.6	15.0	41.0	19.6	63.6 %

CONDUCTIVITY CHANGES THROUGH SEPARATION PROCESSES

Other processes that are used in wastewater treatment is separation processes such as sedimentation, where particles in the water are separated. Separation of solid particles do not change the conductivity of the wastewater. At the experimental plant Sjöstadverket in Stockholm a drum filter was used for separation of suspended solids SS before a membrane bioreactor. Table 4 shows SS, phosphate content and conductivity before and after filtration (Karczewska, 2006). A large reduction of SS was achieved but no reduction of phosphate content and conductivity. The ions in the wastewater, which gives conductivity, pass through the filter.

Table 4. Suspended solids SS, phosphate and conductivity at filtration of incoming wastewater to the experimental plant Sjöstadverket, Stockholm (Karczewska, 2006).

Test Nr.	SS In mg/L	SS Out mg/L	SS red %	PO ₄ -P In mg/L	PO ₄ -P Out mg/L	PO ₄ -P reduc %	Cond. In mS/m	Cond. Out mS/m	Cond. Red %
1	244	62	75	7.4	7.26	2	76.0	77.2	-2
2	212	82	61	6.47	6.07	6	69.3	70.0	-1
3	270	80	70	7.19	6.61	8	77.6	76.2	2
4	252	72	71	6.47	6.33	2	77.5	75.0	3

Figure 6 shows phosphate versus conductivity in incoming wastewater and the co variation was found to be about 10 mSm²/g P. This is larger than if the covariation is only caused by variation in phosphate concentration, which will be 107 μSm²/g P. If also an increase of counter ions is included the co variation will be about 300 μSm²/g P. This shows that the concentration of other ions in the wastewater co variants with the phosphate concentration. Then the content of urine and faeces in the sewage increase the concentration of all species increase including phosphate.

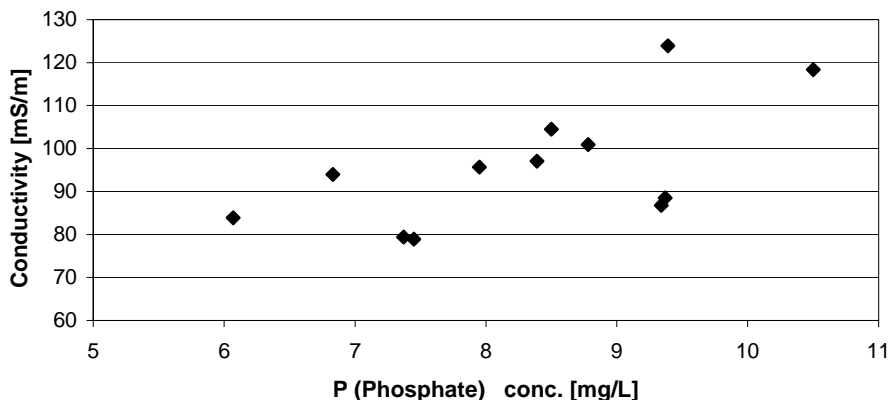


Figure 6. Phosphate content versus conductivity in incoming wastewater to the experimental plant Sjöstadverket, Stockholm (Karczewska, 2006).

However, separation of salt from the water with use of reverse osmosis create changes in the conductivity. At the experimental plant Sjöstadverket in Stockholm reverse osmosis there tested as final treatment step for separation of nutrients from the wastewater (Kieniewicz, 2006). Table 5 shows conductivity pH, flow, total solids TS and concentrations of phosphate, nitrate and ammonia. TS was measured by evaporating the water and therefore also includes dissolved salts that is precipitated at evaporation. The results shows a large increase of conductivity in the concentrate and a decrease in the permeate. Conductivity measurement is therefore useful to control reverse osmosis processes.

Table 5. Conductivity, pH from an final treatment step for separation of nutrients from the wastewater at the experimental plant Sjöstadverket, Stockholm (Kieniewicz, 2006).

	Volyme %	Conduct. mS/m	PH	PO ₄ -P mg/L	NO ₃ -N mg/L	NH ₄ -N mg/L	TS mg/L	Flow l/m ² h
Inflow	100	67.8	5.5	9.14	0.77	36.7	0.46	-
Permeate VR1	-	0.87	4.1	0.045	0.045	0.41	-	30
Concentrate VR1	-	71.2	5.6	8.91	0.60	36.3	0.52	-
Permeate VR2	50	1.15	4.15	0.042	0.045	0.58	-	29.2
Concentrate VR2	50	131	5.95	17.3	0.82	76	0.87	-
Permeate VR5	30	2.6	4.5	0.129	0.074	1.27	-	28.6
Concentrate VR5	20	307	6.25	44.65	2.16	188	2.38	-
Permeate VR10	10	2.73	4.9	0.152	0.107	1.88	-	27.1
Concentrate VR10	10	523	6.3	80.5	3.93	316	4.27	-
Permeate VR20	5	6.55	5.0	0.169	0.173	3.04	-	25.0
Concentrate VR20	5	952	6.43	149.6	7.54	684	8.53	-
Permeate VR30	1.67	9.73	5.2	0.205	0.271	4.75	-	22.8
Concentrate VR30	3.33	1380	6.5	195	12.90	1038	13.11	-

Removal of phosphorus by chemical precipitation and separation of precipitated particles may not change the conductivity. The conductivity decrease from precipitation of phosphate ions is substituted by sulfate ions added with the precipitation chemicals. However, conductivity can be

used to estimate the need of chemicals for precipitation, since the conductivity variation follows the variation of phosphate content. Then the wastewater is diluted with storm water both conductivity and phosphate content decreases.

CONCLUSION

Conductivity measurements can be used to monitor the processes in wastewater treatment that causes changes in conductivity. The processes that in many treatment plants causes changes in conductivity are biological phosphorus and nitrogen removal.

- Biological phosphorus removal will give a reduction with 344 to 278 $\mu\text{Sm}^2/\text{g P}$. However, since the contribution of phosphate ions can be calculated to about 1 % of measured conductivity phosphorus removal will not give any decrease in conductivity.
- At chemical phosphorus precipitation phosphate ions will substituted with sulfate and no reduction in conductivity will be achieved.
- Biological nitrogen removal will consume alkalinity or hydroxide ions. If the amount of available alkalinity is high enough (one mole alkalinity per mole ammonia) biological nitrogen removal through nitrification followed by denitrification will give a decrease of conductivity with 842 $\mu\text{Sm}^2/\text{g N}$.
- Since ammonium nitrogen and alkalinity, which is reduced at biological nitrogen removal, contributes to conductivity with about 33 % and 14 % respectively, it is plant with biological nitrogen removal that has a decrease in conductivity in the treatment process.
- Separation of suspended solids through sedimentation or filtration will give no changes in conductivity.
- Separation of nutrients through reverse osmosis will give large changes in conductivity and conductivity can thus be used for controlling the process.

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REFERENCES

- Aguado D., Montoya T., Ferrer J. och Seco A. (2006) Relating ions concentration variations to conductivity variations in a sequencing batch reactor operated for enhanced biological phosphorus removal. *Env. Mod. & Software* 21 (6): 845-851.
- Barat R., Montoya T., Borrás L., Seco A. and Ferrer J. (2005) Calcium effect on enhanced biological phosphorus removal. *IWA Conf. Nutrient Management in Wastewater Treatment Processes and Recycle Streams*, Krakow Poland, 19-21 September 2005, 59-68.
- CRC Handbook of Chemistry and Physics (1999) Lide D.R. (editor), 80th edition, ISBN 0-8493-0480-6.
- Eklund C. (2007) Personal communication, Gävle Vatten, Gävle.
- Eskilstuna, Gävle, Karlstad, Linköping, Norrköping, Uppsala, Västerås and Örebro (2002) Riktlinjer för utsläpp av avloppsvatten från industrier och andra verksamheter.
- Hellström T., Book K., Rennerfelt J. and Willers H. (2001) Underlag för gränsvärdeslista. VA-Forsk 2001-03.
- Fagerström T.-O. (2006) Personal communication, VA-verket, City of Mariehamn Finland.

- Howard I., Espigares E., Lardelli P., Martín J. L. och Espigares M. (2004) Evaluation of microbiological and physicochemical indicators for wastewater treatment, *Environmental Toxicology* 19 (3) 241-249
- Karczewska K. (2006) Rotary drum filter as pretreatment for a membrane bioreactor – Operation, evaluation and optimization. Master Thesis at Dep. for Land and Water resources Engineering KTH. TRITA-LWR-EX-06-20.
- Kieniewicz A. (2006) A reverse osmosis (RO) plant for sewage treatment and nutrient recovery - The influence of pre-treatment methods. Master Thesis at Dep. for Land and Water resources Engineering KTH. TRITA-LWR-EX-06-08.
- Levlin E. and Hultman B. (2008) Konduktivitetmätningar som mät- och kontrollmetod vid kommunala avloppsanläggningar, *svenskt Vatten Utveckling* Nr 2008-04.
- Magnusson J. (2003) Sammansättning av hushållsspillvatten från Hammarby Sjöstad: Hushållens bidrag av farliga ämnen till avloppsvattnet. Master Thesis work, Inst. för Samhällsbyggnadsteknik Luleå Tekniska Universitet 2003:292 CIV, ISSN 1402-1617.
- Maurer M. and Gujer W. (1995) Monitoring of microbial phosphorus release in batch experiments using electric conductivity. *Wat. Res.* 29 (11) 2613-2617.