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(54) **Titre : ABSORBANT AQUEUX DE CO2 COMPRENANT DU 2-AMINO-2-METHYL-1-PROPANOL ET DU 3-AMINO-PROPANOL OU DU 2-AMINO-2-METHYL-1-PROPANOL ET DU 4-AMINO-BUTANOL**
(54) **Title: AN AQUEOUS CO2 ABSORBENT COMPRISING 2-AMINO-2-METHYL-1-PROPANOL AND 3-AMINOPROPANOL OR 2-AMINO-2-METHYL-1 -PROPANOL AND 4- AMINOBUTANOL**

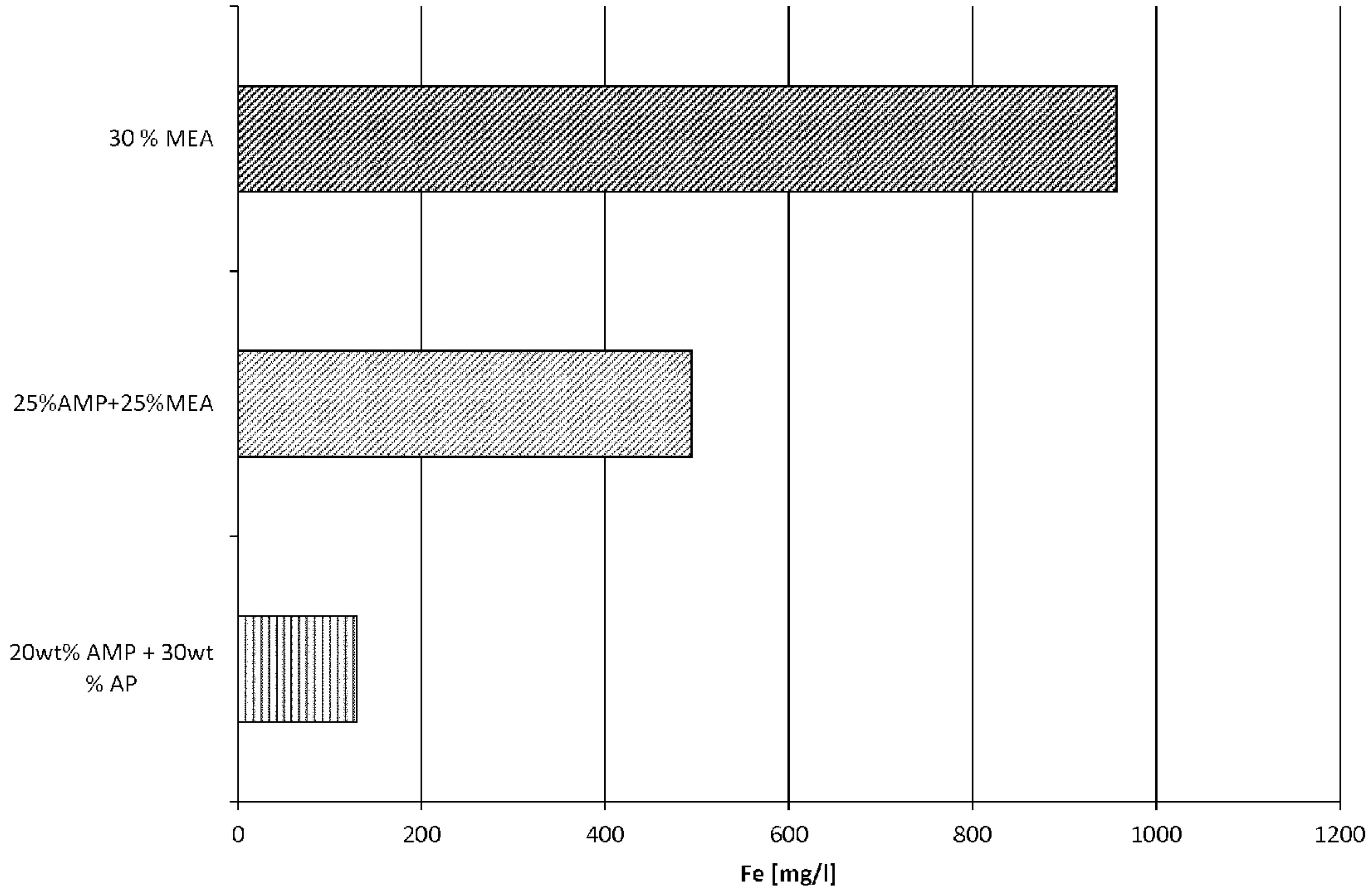

Fig. 4

(57) **Abrégé/Abstract:**
An aqueous CO2 absorbent comprising a combination of 2-amino-2-methyl-1 - propanol (AMP) and 3-aminopropanol (AP), or AMP and 4-aminobutanol (AB), is described. A method for capturing CO2 from a CO2 containing gas using the mentioned absorbent, and the use of a combination of AMP and AP, or a combination of AMP and AB are also described.

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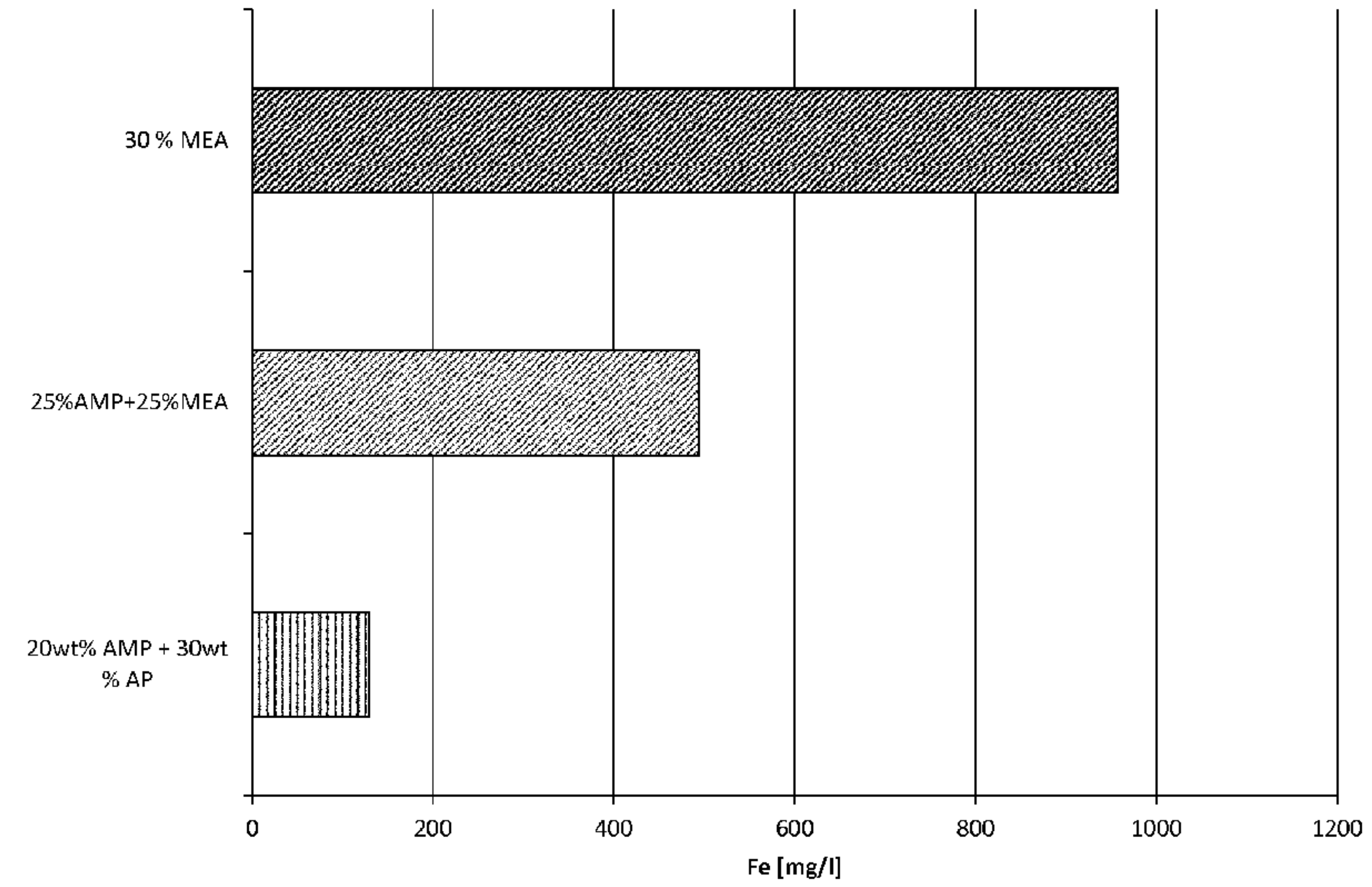

Fig. 4

(57) **Abstract**: An aqueous CO2 absorbent comprising a combination of 2-amino-2-methyl-1 - propanol (AMP) and 3-aminopropanol (AP), or AMP and 4-aminobutanol (AB), is described. A method for capturing CO2 from a CO2 containing gas using the mentioned absorbent, and the use of a combination of AMP and AP, or a combination of AMP and AB are also described.

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AN AQUEOUS CO2 ABSORBENT COMPRISING 2-AMINO-2-METHYL-1-PROPANOL AND 3-AMINOPROPANOL OR 2-AMINO-2-METHYL-1 -PROPANOL AND 4- AMINOBUTANOL

Description

Technical Field

[0001] The present invention relates to an improved method for capturing of CO_2 from a combustion gas, and to an improved amine absorbent for CO_2.

Background Art

[0002] Capture of CO_2 from a mixture of gases in an industrial scale has been known for decades, i.e. for separation of natural gas and CO_2 from sub terrain gas wells to give natural gas for export and CO_2 for return to the sub terrain structure.

[0003] The growing concern on environment and the greenhouse effect of CO_2 from combustion of fossil fuels has caused a growing interest in CO_2 capture from major points of emission of CO_2 such as thermal power plants, in so called Post Combustion CO_2 capture

[0004] Even if power plants represent the largest point sources for CO_2 emissions, other industries like steelworks and cement plants can utilize similar technologies for CO_2 capture.

[0005] US 5.618.506, and EP 0 558 019, both to The Kansai Electric Power Co., Inc., and Mitsubishi Jukogyo Kabushiki Kaisha, and the citations indicated therein, give a general background of process and absorbents for capturing of CO_2.

[0006] Industrial CO_2 capturing plants include an absorber, in which a liquid absorbent is brought into countercurrent contact with the gas to be treated. A “purified” or low CO_2 gas is withdrawn at the top of the absorber and is released into the atmosphere, whereas a CO_2 rich absorbent is withdrawn from the bottom of the absorber. The rich absorbent is regenerated in a regeneration column where the rich absorbent is stripped by countercurrent flow with steam that is generated by heating of regenerated absorbent at the bottom of the regeneration column. The regenerated absorbent is withdrawn from the bottom of the regeneration column and is recycled into the absorber. A CO_2 rich gas, mainly comprising steam and CO_2 is withdrawn from the top of the regeneration column. The CO_2 rich gas is treated further to remove water, and compressed before the CO_2 is sent for deposition or other use.

[0007] Capture of CO_2 is, however, an energy demanding process, as the binding of CO_2 to the absorbent is an exothermal reaction and the regeneration is an endothermal reaction. Accordingly, heat is lost in the absorber and heat is to be added to the regeneration column to regenerate the absorbent and release the CO_2. This heat demand is a major operating cost for a plant for CO_2 capture. A reduction of the heat requirement for regeneration of the absorbent is therefore sought to reduce the energy cost for the CO_2 capture.

[0008] Many different amines and combinations have been suggested as absorbents for CO_2, the different amines having CO_2 absorption capabilities, see e.g. the above-mentioned patents. Examples of suggested amines for the aqueous solutions to be used as absorbents are alkanolamines such as e.g. monoethanol amine (MEA), diethanol amine (DEA), triethanol amine (TEA), methyldiethanolamine (MDEA), diisopropanol amine (DIPA), diglycol amine (DGA), methyl monoethanol amine (MMEA), 2-amino-2-methyl-1-propanole (AMP). MEA is also commonly used as a reference absorbent in tests for possible new absorbents.

[0009] The reaction kinetics, heat demand, heat of reaction, amine equilibrium loading, degradation, stability, solubility in water and absorption capacity of the different amines are of interest when selecting a potential absorbent for industrial scale CO_2 capture.

[0010] Amines are also prone to degradation and are corrosive in the environment where they are used. Amines are degraded both by thermal degradation and oxidative degradation, via different mechanisms. Degradation is unwanted, both as degradation inactivates the absorbent and causes a need for make-up filling of amine into the plant, as potentially large amounts of waste products are produced, and as the long term operation will be more dependent of a reclaimer unit to recover usable amines bound to degradation products (so called Heat Stable Amine Salts).

[0011] As opposed to earlier applications of amine based absorption technology like natural gas treatment, when capturing from flue gas, the treated gas is released to the atmosphere. This implies a risk for emissions of volatile amine components or degradation products to the environment.

[0012] Amines with less degradation will therefore cause less emission of degradation products in the cleaned exhaust gas leaving the plant.

[0013] Recent developments in amine technology have revealed that reactions between NOx in the flue gas and secondary amines in the solvent may lead to formation of a group of carcinogenic compounds called nitrosamines. Secondary amines may be present as part of the solvent or formed as degradation products. Nitrosamines formation is limited by avoiding the use of secondary amines and by limiting solvent degradation.

[0014] Corrosion is of concern both as it is detrimental for important parts of the plant and may reduce the life expectancy thereof, or cause a requirement for more expensive construction elements, and as products of corrosion, such as Fe-ions, may be detrimental to the absorbent by causing higher degree of degradation.

[0015] WO2010134926A1 relates to low-volatile aqueous compositions comprising a thermally stable amine and water. A number of thermally stable amines, said to thermally stable up to 130 to 170 °C, are listed. Amongst the mentioned amines are found piperazine (PZ), substituted piperazines, 2-amino-2-methyl-1-propanol (AMP), and different amino alkyl alcohols, such as 3-amino-1-propanol (AP), 4-amino-1-butanol (AB), etc. There is no indication on oxidative degradation at lower temperatures, or the effect of the amines on corrosion.

[0016] CO_2 Absorption into Aqueous Solutions of a Polyamine (PZEA), a Sterically Hindered Amine (AMP), and their Blends, Chemical Engineering & Technology, Volume 33, Issue 3, pages 461-467, March, 2010, describes testing of aqueous solutions of amines and mixtures of amines and the performance of the tested amine solutions in CO_2 capture. The use of PZEA as an activator for MEA, PMEA and MEA solutions are described.

[0017] Structure and activity relationships for amine based CO2 absorbents-I, International Journal of Greenhouse Gas Control 1 (2007), page 5–10, relates to testing of CO_2 absorption properties of amines, such as amine alkyl alcohols, as a function of chain length. Stability of the absorbents was not discussed in this publication.

[0018] The objective of the present invention is to provide an improved absorbent and an improved method for capturing of CO_2 from a CO_2 containing gas, where the improved absorbents has improved resistance to oxidative degradation and is less corrosive to the construction materials commonly used, compared to standard absorbents. An additional objective is to provide an absorbent with low risk of nitrosamine formation. An additional objective is to provide an improved absorbent and a method for capturing CO_2 having a lower energy demand for regeneration of the absorbent, at the same time as acceptable reaction kinetics and absorption capacity is obtained. It is also an object to provide a method for use of the new absorbent.

Summary of invention

[0019] According to a first aspect, the invention relates to an aqueous CO_2 absorbent comprising a combination of 2-amino-2-methyl-1-propanol (AMP) and 3-amino-1-propanol (AP), or AMP and 4-amino-1-butanol (AB).

[0020] It has surprisingly been found that a CO_2 absorbent comprising AMP and AP, or AMP and AB, is far less prone to oxidative degradation than other well known “standard” absorbents, such as MEA alone or MEA in combination with AMP. Additionally, the present absorbent is far less corrosive, both in laboratory tests and in a pilot plant. Liberation of ions into the absorbent caused by corrosion is known to increase the oxidative degradation of amines. Accordingly, as the present absorbent is less corrosive to the parts in the plant, less ions are liberated into the absorbent adding to the inherent resistance towards oxidative degradation for the present amine absorbent.

[0021] As the present absorbents are primary amines, the formation of nitrosamines is believed to be substantially reduced in using the present absorbents for CO_2 capture. Also, as the present absorbents are less prone to degradation, the formation of nitrosamines is believed to be substantially reduced in using the present absorbents for CO_2 capture. Additionally, the present absorbents are found to be promising candidates for industrial scale plants as measured in test for absorption rate and desorption rates, respectively, vs. CO_2 concentration.

[0022] According to a first embodiment the concentration of AMP is from 10 to 35 % by weight and the concentration of AP or AB is from 10 to 40% by weight. The upper limit for the concentration of AMP is set due to precipitation formed upon reaction with CO_2 at higher concentrations of AMP in an aqueous solution. Traditionally the total concentration of solutes in an aqueous absorbent is limited to about 50 % by weight to avoid too high viscosity of the solution, and due to the requirement for a certain amount of water. 50 % by weight total concentration of AMP and AB or AP is, however, no absolute limit. It is, however, presently assumed that the total concentration in an operating plant will be lower than 60 % by weight, such as 50 % by weight or lower.

[0023] According to one embodiment, the concentration of AMP is at least 10 % by weight, such as at least 20 % by weight, such as at least 25% by weight, or at least 30 % by weight. The concentration of AP or AB is at least 10 % by weight, such as at least 20 % by weight, such as at least 25% by weight, or at least 40 % by weight.

[0024] According to an embodiment, the absorbent comprises a combination of AMP and AP.

[0025] According to a second aspect, the present invention relates to a method for capturing CO_2 from an CO_2 containing gas, such as an exhaust gas from a thermal power plant or an industrial plant, where the CO_2 containing gas is brought in countercurrent flow to a CO_2 absorbent in an absorber to give a CO_2 depleted gas that is released into the surroundings, and a CO_2 rich absorbent that is collected in the bottom of the absorber, regenerated and recycled into the absorber, wherein the CO_2 absorbent is an absorbent as described above.

[0026] According to a third aspect, the present invention relates to a use of an aqueous solution of a combination of AMP and AP or AMP and AB as an absorbent for CO_2 in a method for capturing CO_2 from a CO_2 containing gas.

[0027] According to one embodiment, AMP is used in a concentration from 10 to 35 % by weight, and AP or AB is used in a concentration from 10 to 40 % by weight.

Brief description of drawings

[0028]

Fig. 1 is a plot of absorption rate vs. CO_2 concentration for a comparative absorbent and two absorbents according to the invention,
Fig. 2 is a plot of desorption rate vs. CO_2 concentration for a comparative absorbent and two absorbents according to the invention,
Fig. 3 visualizes test of oxidative degradation of two comparative absorbents and one absorbent according to the invention, in the presence and absence of Fe ions,
fig. 4 visualizes the results from test of corrosive effect of two comparative absorbents, and one absorbent according to the invention,
Fig. 5 is a principle sketch of a pilot plant used for testing,
Fig. 6 visualizes results for corrosion as concentration of Fe ions in the absorbents in a pilot plant as a function of hours of operation;
Fig. 7 visualizes results for corrosion as concentration of Cr ions in the absorbents in a pilot plant as a function of hours of operation,
Fig. 8 visualizes results for corrosion as concentration of Ni ions in the absorbents in a pilot plant as a function of hours of operation,
Fig. 9 visualizes results for relative degradation for different amines after 1000 hours of use in a pilot plant, and
Fig 10 visualizes the results for formation of nitrosamines after 1000 hours of use in a pilot plant.

Detailed description of the invention

[0029] The present invention relates to an improved amine absorbent for CO_2 capture and a method for capturing CO_2 using the improved amine absorbent.

[0030] The invention is based on mixing two different primary amines having different reaction kinetics, one being a sterically hindered amine, namely

2-amino-2-methyl-1-propanol (AMP) and the other being a monoalkanolamine, namely 3-aminopropanol (AP), or 4-aminobutanol (AB).

[0031] AMP, being a sterically hindered amine, is known to have low energy requirement for regeneration of the absorbent but the slow reaction kinetics have a negative impact in the absorber as it requires a longer contact time between the CO_2 containing gas and the absorbent in the absorber. As opposed to the reference amine, MEA, commonly used in 30wt%, corresponding to a molar concentration of 5 mol/l, AMP cannot be used alone in higher concentrations than about 4 mol/l, corresponding to about 35 % by weight, due to precipitation formed upon reaction with CO_2.This limits the absorption capacity of AMP, unless a second component is used in combination.

[0032] AP and AB on the other side are known to have high energy requirement but faster reaction kinetics. Figures 1 and 2 show that AMP + AP has higher cyclic capacity and is better with regard to stripping than the industry reference MEA, which implies that A+B has lower energy requirement than MEA as an absorbent for post combustion CO_2 capture.

[0033] According to the present invention it is found that an aqueous CO_2 absorbent comprising from 10 to 35 % by weight of AMP and from 10 to 40 % by weight of AP or AB, are substantially less prone to thermal and oxidative degradation than the industry standard absorbent MEA. Additionally, the novel absorbent shows good reaction kinetics, absorption capacity, and low energy requirement.

[0034] It is preferred that at least 15% by weight, such as e.g. at least 20 % by weight or at least 25 % by weight, such as about 30 % by weight, AMP is present in the absorbent. It is also preferred that at least 15% by weight, such as e.g. at least 20 % by weight or at least 25 % by weight such as about 30 % by weight, AP or AB, is present in the absorbent.

[0035] The above mentioned concentrations of the amines corresponds to a total amine concentration of 50% in aqueous solution and a weight ratio of AMP to AP or AB from 10:40 to 35:15, such as e.g. 10:40 to 35:15, 20:30 to 30:20, 25:25. Below, different tests of examples of absorbents according to the present invention and comparative examples using MEA alone have been performed. The experimental part is divided in a first introductory part of screening experiments for a preliminary relative comparison of important characteristics of different test absorbents, such as rate of absorption, absorption capacity, cyclic capacity, viscosity and absorption equilibrium, and second part including tests run in a pilot plant.

Screening experiments

[0036] Screening experiments were performed to get a first indication of the absorption rate and desorption rate of the candidate amine mixtures compared to 30% by weight MEA (5M) as an industry reference. The rate of absorption is a measure of the mass transfer enhancement properties of an absorbent, which is directly related to the height required for the absorber. With a faster reacting absorbent the absorber tower height can be reduced. The cyclic capacity of the solvent is the difference between the attainable CO_2 loading at absorption conditions and the minimum CO_2 loading achieved at desorption conditions. Absorption/desorption from flue gas is based upon temperature swing as the most important mechanism. Solvents with significant temperature sensitivity in their absorption capacity will have a higher cyclic capacity, thereby requiring less liquid circulation per mole CO_2 captured and require less energy. In the real process, desorption is typically performed at 110-130 °C. The desorption screening curves, based upon increasing the temperature from 40 °C (absorption screening condition) to 80 °C gives an important relative comparison of temperature sensitivity and cyclic capacity for different solvents.

[0037] The tests were performed at an apparatus designed to give a fast relative comparison of the rate of absorption and the absorption capacity of solvents with a potential for utilization in an industrial absorption process. The method of comparison has been used for comparative studies since 1993 (see e.g. Erga et al., 1995). Being an apparatus for relative comparison, the interpretation of results relies on the specification of a base-case amine with a specific concentration.

[0038] The rate of absorption is a measure of the mass transfer enhancement properties of an absorbent, which is directly related to the height required for the absorber. With a faster reacting absorbent the tower heights can normally be reduced. The absorption capacity of the solvent is an important property as a premise for a high cyclic capacity of the process. Additional observations from the screening experiments can be made regarding the extent of foaming, possible precipitation, and discoloration upon CO_2 loading which may be indicative of solvent degradation. The screening tests are performed to give indications for selection of appropriate concentration levels of AMP and AP.

[0039] Different concentrations of AP/AMP were tested, and compared with 5M (30% by weight) MEA. The reproducibility has been controlled by reproducing the 30% MEA test.

[0040] The absorption capacity of the solvent is an important premise for maximizing the cyclic capacity of the process. With MEA and AP the capacity for absorption is limited by the reaction stoichiometry to about 0.5 mole CO_2/mole amine at ambient pressure. As AMP is a sterically hindered amine and forms bicarbonate, it can be loaded to more than 0.5 mole CO_2/mole amine depending of the CO_2 partial pressure with a theoretical maximum loading of 1.0. It must, however, be noted that for the cyclic capacity to be high with AMP, a high CO_2 equilibrium pressure at absorption conditions is also necessary.

[0041] The mass transfer screening apparatus is used to measure the absorption rate of CO_2 at 40°C followed by desorption rate measurements with nitrogen at 80°C. The gas is distributed through the diffuser of sintered glass which creates gas-bubbles rising up through the liquid. From the surface of these bubbles, CO_2 is first absorbed into the liquid at 40°C until 95% of equilibrium, corresponding to 9.5% CO_2 in the effluent gas, is obtained. Afterwards the rich solution is heated to 80°C, and desorption starts with pure nitrogen until the CO_2 concentration in the effluent gas decreases to 1 vol%. A computer controls the solenoid valve system for gas supply and cooling or heating of the water bath.

[0042] The CO_2-content of the effluent gas is measured by an IR CO_2 analyzer. After each experiment the accumulated weight of liquid is measured and compared with the net absorbed amount of CO_2. This is to assure that no solvent is lost by evaporation. Samples of the solvent are also taken for CO_2 analysis after the absorption and desorption sequence.

Results for AMP, and AMP+AP

[0043] Figure 1 illustrates the results for absorption rate vs. CO_2 concentration obtained with the following alkanolamine concentrations in aqueous solvent of 20% by weight solution of AMP + 30 % by weight of AP, 26.7 % by weight of AMP + 22.5 % by weight of AP and 30 % by weight of MEA, whereas figure 2 illustrates the desorption rate vs. CO_2 concentration for the same absorbents.

[0044] Figure 1 shows that the 20 % by weight of AMP + 30 % by weight of AP amine solution has an absorption rate comparable to MEA, and higher capacity. The 26.7 % by weight of AMP + 22.5 % by weight of AP, has both lower absorption rate and lower capacity than MEA but is still a promising candidate as an absorbent.

[0045] Figure 2 indicates that both the amine solutions comprising AMP + AP has higher net CO_2 capacity than MEA alone. Accordingly both the AMP + AP solutions are promising as CO_2 absorbents.

Oxidative degradation

[0046] Oxidative degradation experiments were done by sparging a reaction gas containing air and CO_2 through a glass sinter into an amine solution preloaded with CO_2 in a glass reaction vessel. The gas flow rate and the composition of the reaction gas are controlled by the mass flow controllers (MFC).The reaction vessel has a thermostatic jacket which is connected to a water bath in order to obtain a constant temperature of 55°C. At the top of the reaction vessel two 400 mm intensive condensers are connected which are cooled with tap water. After the condensers the gas is led through a gas washing bottle before it is going to a vented fume hood. Experiments are run for approximately 500 hrs and samples are taken for amine analysis on regularly intervals. The difference between the start and end concentration of amine gives a measure of the amine degradation.

[0047] Figure 3 illustrates the oxidative degradation of three different amine absorbents for CO_2, in the absence and in the presence of Fe ions. The three different amine solutions where 20 % by weight AMP + 30 % by weight AP (an absorbent according to the present invention), 25 % by weight MEA + 25 % by weight AMP, and 30 % by weight MEA.

[0048] The results visualized in figure indicates that the absorbent according to the present invention, i.e. the 20 % by weight AMP + 30 % by weight AP shows a substantially improved resistance to degradation than the absorbents comprising MEA + AMP or MEA alone, both in the absence and presence of Fe ions in the solution.

[0049] The tests including Fe ions illustrate how the rate of degradation may be influenced by Fe ions resulting from corrosion of ferrous materials in the plant. It is clear that Fe ions increases the degradation for all the absorbents tested.

Corrosive effect of absorbents

[0050] Experiments on the corrosive effect of the CO_2–amines–water system were performed using stainless steel cells (316SS, OD = ½", thickness = 1.7 mm). Each cell had a volume of about 27 cm^3 and is equipped by a Swagalok valve. A set of experiment consisted of 5 cells. Each cell was flushed with N2 (99.999%) to purge air within the cell. A certain amount of CO_2-loaded amine solution (~15 cm^3) was then injected into the cell and the top of the cell was flushed with N2 before closing the valve to ensure that there is no air within the cell. The cells were then placed in a forced convection oven at 135°C for 5 weeks. One cell was taken every week for analysis of metals by inductively coupled plasma mass spectroscopy (ICP-MS).

[0051] Figure 4 illustrates the corrosive effect of different aqueous amine CO_2 absorbents, measured according to the above-described procedure. The concentration of Fe ions in the amine solution after the test period is a clear indication on the corrosive effect of the amine solution in a standardized test.

[0052] The results illustrated in figure 4 clearly indicate that the absorbent according to the present invention is far less corrosive than MEA + AMP or MEA alone.

[0053] By combining the results for oxidative degradation in the presence and absence of Fe ions and the corrosive effect of the tested amine absorbents, it is highly likely that the absorbent according to the present invention will be far less prone to oxidative degradation in a CO_2 capture plant due to two different effects. Firstly, the present absorbent shows lower degradation rate than the comparative absorbents, both in the presence and absence of Fe ions in an oxidative degradation under standardized conditions and concentration of Fe ions. Secondly, the corrosive effect of the present absorbent is substantially lower than for the comparative absorbents. This means that the concentration of Fe ions in the absorbent circulating in a plant will remain low for a longer period, and the concentration of Fe ions will most probably remain lower during the lifetime of the plant, by using the present absorbent. This is an indication that the degradation of the present absorbent will be substantially lower than the comparative absorbents in a CO_2 capture plant.

Tests on a Pilot Plant

[0054] A test campaign was performed in a small pilot plant for Post Combustion CO2 absorption as illustrated in figure 5. Exhaust gas, generated by means of a propane burner which can be adapted to natural gas or coal derived flue gas by mixing with air or recycling of CO2, respectively, is introduced through an exhaust pipe 1. The exhaust gas in the exhaust pipe is introduced into a direct contact cooler 2 where the exhaust gas is washed and humidified by countercurrent flow to water. The cooled and humidified exhaust gas is then introduced into an absorber, where the exhaust gas is brought in countercurrent flow to an aqueous absorbent introduced through a lean amine pipe 4, in a not shown packing. Rich absorbent having absorbed CO_2 is collected at the bottom of the absorber and is withdrawn trough a rich absorbent pipe 5, whereas the CO_2 lean exhaust gas is released into the surroundings through lean exhaust pipe 6 after being washed in washing sections by means of water recycled through washing water cooling circuits 19, 19’.

[0055] The rich absorbent in pipe 5 is heated against the lean absorbent in line 4 by means of a heat exchanger 7 before being introduced into a regeneration column 8 where the rich absorbent is stripped by countercurrent flow to steam. The stripping steam is generated in a reboiler 11 in which lean absorbent collected at the bottom of the regeneration column is introduced through a lean absorbent withdrawal pipe 10. Heat for steam production in the reboiler is added by means of steam introduced in steam pipe 13, the steam in pipe 13 is condensed in the reboiler and is withdrawn through condensate pipe 13'.

[0056] Lean absorbent is withdrawn from the reboiler 11 in lean absorbent pipe 4 and recycled into toe absorber. Steam and CO_2 liberated from the absorbent in the regeneration column is washed in not shown washing sections by countercurrent flow to water recirculating in washing water cooling circuits 20, 201, before being withdrawn through CO_2 collection pipe 9. The CO_2 and steam is cooled in a cooler 14, flashed in a flash drum 15 to give water that is recycled into the regeneration column through a recycling line 17, and partly dried CO_2 that is withdrawn through a pipe 16 for further treatment.

[0057] The pilot has an absorber packing height of 19.5 m, a desorber height of 13.6 m and is well equipped with sampling ports for gas and liquid, temperature and pressure probes and measurements of gas/liquid flow in all parts of the plant.

[0058] Test samples were withdrawn at times indicated in figures 6, 7, 8, from the absorbent circulating in the pilot plant and the test samples were tested for concentration of Fe, Ni, and Cr ions, as being indicative of corrosive effect of the tested amine absorbents.

[0059] Figures 6, 7, 8 illustrate the concentration of Fe, Ni and Cr ions, respectively, in the amine absorbent during 1000 hours pilot plant operation. The test results clearly indicate that the amine absorbent according to the present invention, 20 % by weight AMP + 30 % by weight AP, is far less corrosive than the comparative absorbents 25 % by weight MEA + and 25 % by weight AMP or 30 % by weight MEA alone.

[0060] Figure 9 illustrates the relative degradation of amine after 1000 hours operation at the pilot plant for 30 % by weight MEA, 25 % by weight MEA + 25 % by weight AMP and 30 % by weight AP + 20 % by weight AMP.

[0061] Formation of nitrosamines is an indication of amine degradation as mentioned in the introduction. Tests were performed for determination of nitrosamine formation during operation of the pilot plant operated as indicated for the pilot plant tests above. Test samples were withdrawn at times indicated in figure 10 and were analyzed for total nitrosamines by head space GC-MS-NCD as released NO after treatment with HCl and CuCl at 70˚C. The method is a modified version of the method described by Wang J. et al. in J. Agric. Food Chem, 2005, 53, 4686-4691. The main instrumental modification is that GC-MS-NCD is used instead of the Sievers Nitric Oxide Analyser.

[0062] Figure 10 shows the development in concentration of total nitrosamines in the amine absorbent during approx. 1000 hours of pilot plant operation. The test results clearly illustrate that nitrosamine formation in the amine absorbent according to the present invention, 20 % by weight AMP + 30 % by weight AP, is significantly reduced compared to amine absorbent containing secondary amine such as 25 % by weight AMP + 15 % by weight PZ.

[0063] The test results visualized in figures 6, 7, 8, 9, 10 confirms that the present aqueous amine absorbents have beneficial effects with regard to corrosive effect on steel, and are less prone to degradation, primarily oxidative degradation than the comparative absorbents tested.

[0064] All the results from the pilot plant operation indicates that the presently claimed amine absorbent is substantially less corrosive and is degraded to a lower degree than the comparative amine absorbents according to the prior art.

Claims

1. An aqueous CO_2 absorbent comprising a combination of 2-amino-2-methyl-1-propanol (AMP) and 3-aminopropanol (AP), or AMP and 4-aminobutanol (AB).
2. The CO_2 absorbent according to claim 1, wherein the concentration of AMP is from 10 to 35 % by weight and the concentration of AP or AB is from 10 to 40% by weight.
3. The CO_2 absorbent according to claim 2, wherein the concentration of AMP is at least 10 % by weight, such as at least 20 % by weight, such as at least 25% by weight, or at least 30 % by weight.
4. The absorbent according to claim 2 or 3, wherein the concentration of AP or AB is at least 10 % by weight, such as at least 20 % by weight, such as at least 25% by weight, or at least 30 % by weight.
5. The absorbent according to any of the preceding claims, wherein the absorbent additionally comprises any conventional additive.
6. The absorbent according to any of the preceding claims, wherein the absorbent comprises a combination of AMP and AP.
7. A method for capturing CO_2 from an CO_2 containing gas, such as an exhaust gas from a thermal power plant or an industrial plant, where the CO_2 containing gas is brought in countercurrent flow to a CO_2 absorbent in an absorber to give a CO_2 depleted gas that is released into the surroundings, and a CO_2 rich absorbent that is collected in the bottom of the absorber, regenerated and recycled into the absorber, wherein the CO_2 absorbent is an aqueous CO_2 absorbent comprising a combination of 2-amino-2-methyl-1-propanol (AMP) and 3-aminopropanol (AP), or AMP and 4-aminobutanol (AB).
8. A use of an aqueous solution of a combination of AMP and AP or AMP and AB as an absorbent for CO_2 in a method for capturing CO_2 from a CO_2 containing gas.
9. The use of claim 8, where AMP is used in a concentration from 10 to 35 % by weight, and AP or AB is used in a concentration from 10 to 40 % by weight.

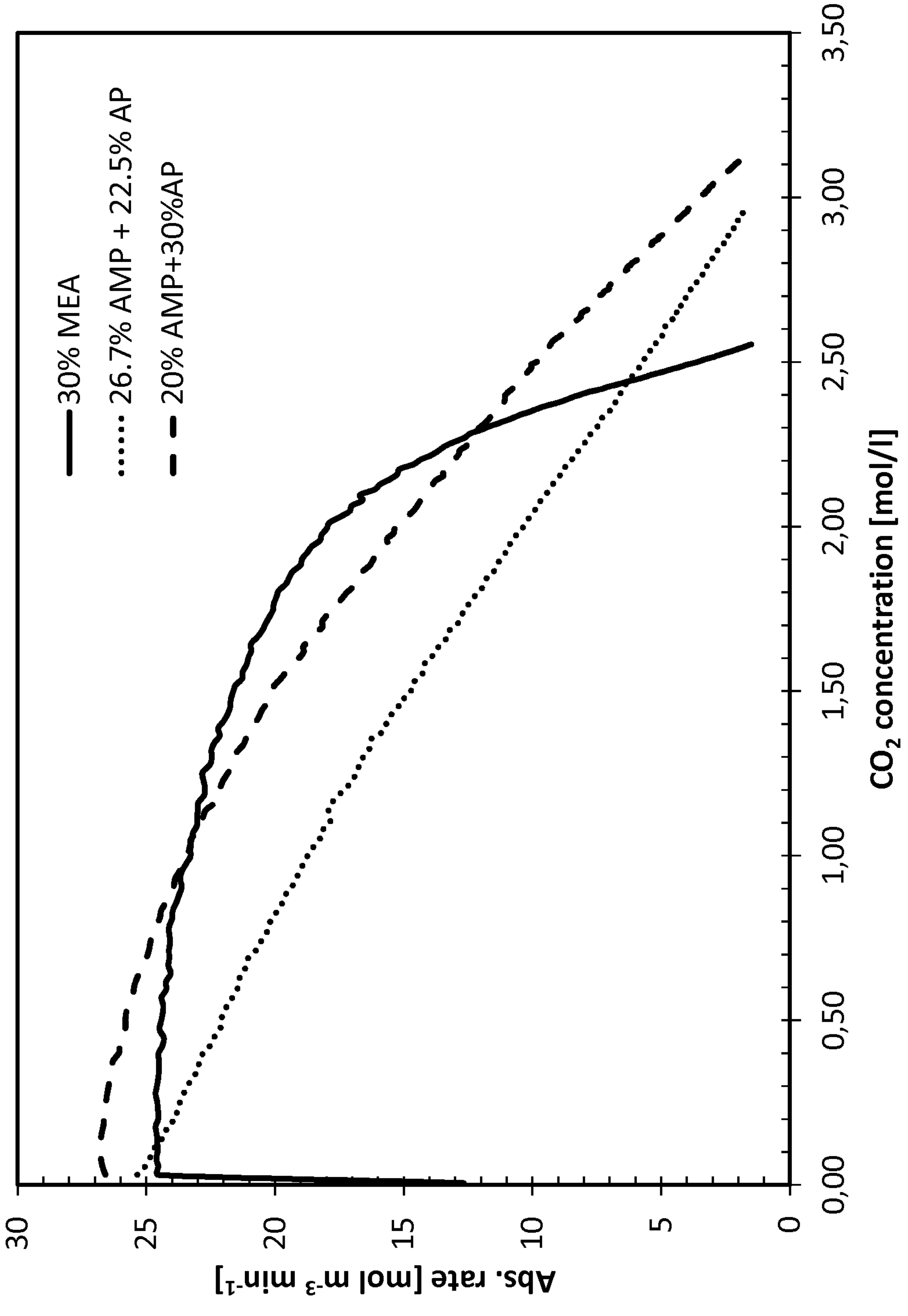
30% MEA
26.7% AMP + 22.5% AP
20% AMP+30%AP
Abs. rate [mol m-3 min-1]
30
25
20
15
10
5
0
0,00
0,50
1,00
1,50
2,00
2,50
3,00
3,50
CO2 concentration [mol/l]

Fig. 1

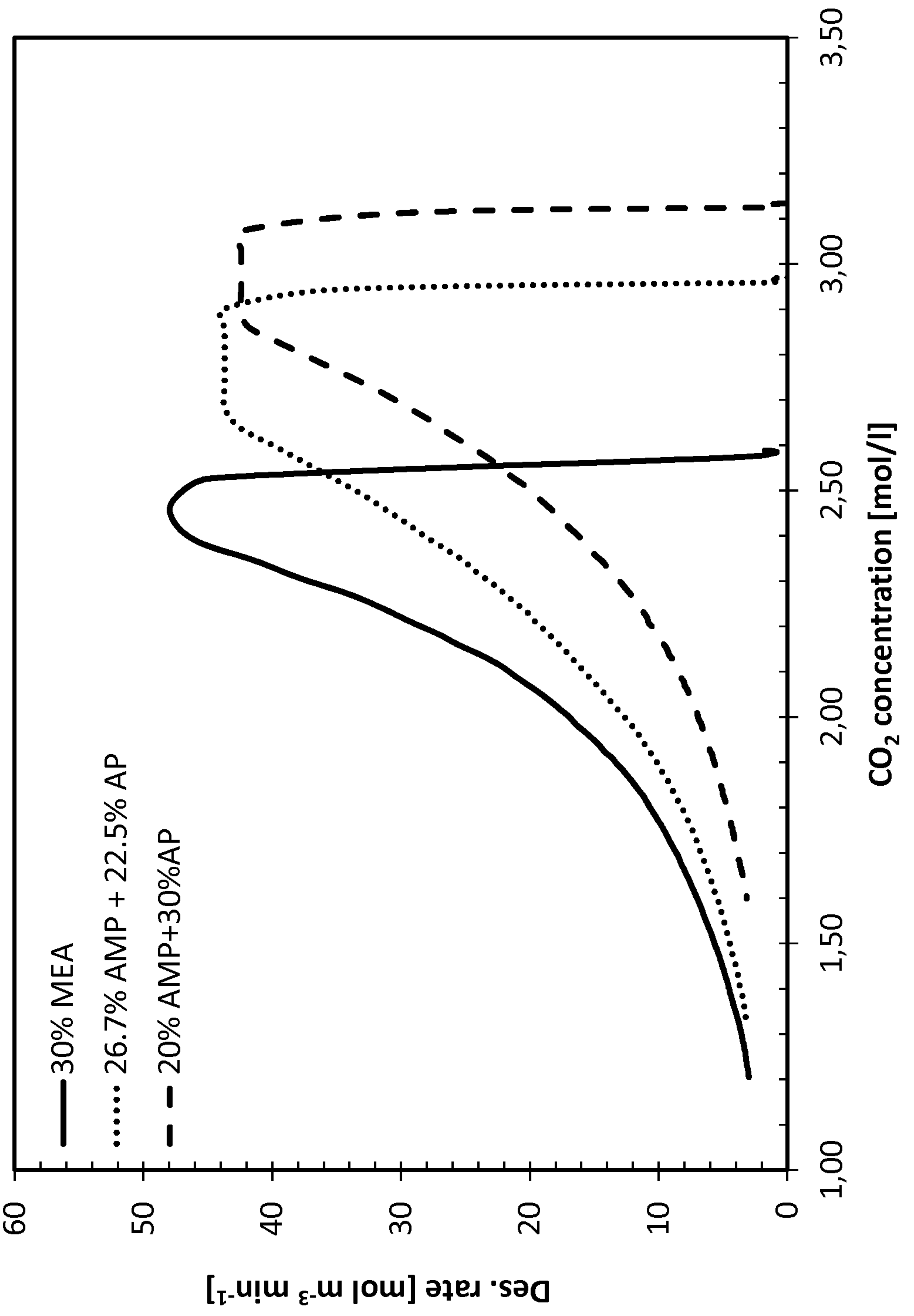
30% MEA
26.7% AMP + 22.5% AP
20% AMP+30%AP
Des. rate [mol m-3 min-1]
60
50
40
30
20
10
0
1,00
1,50
2,00
2,50
3,00
3,50
CO2 concentration [mol/l]

Fig. 2

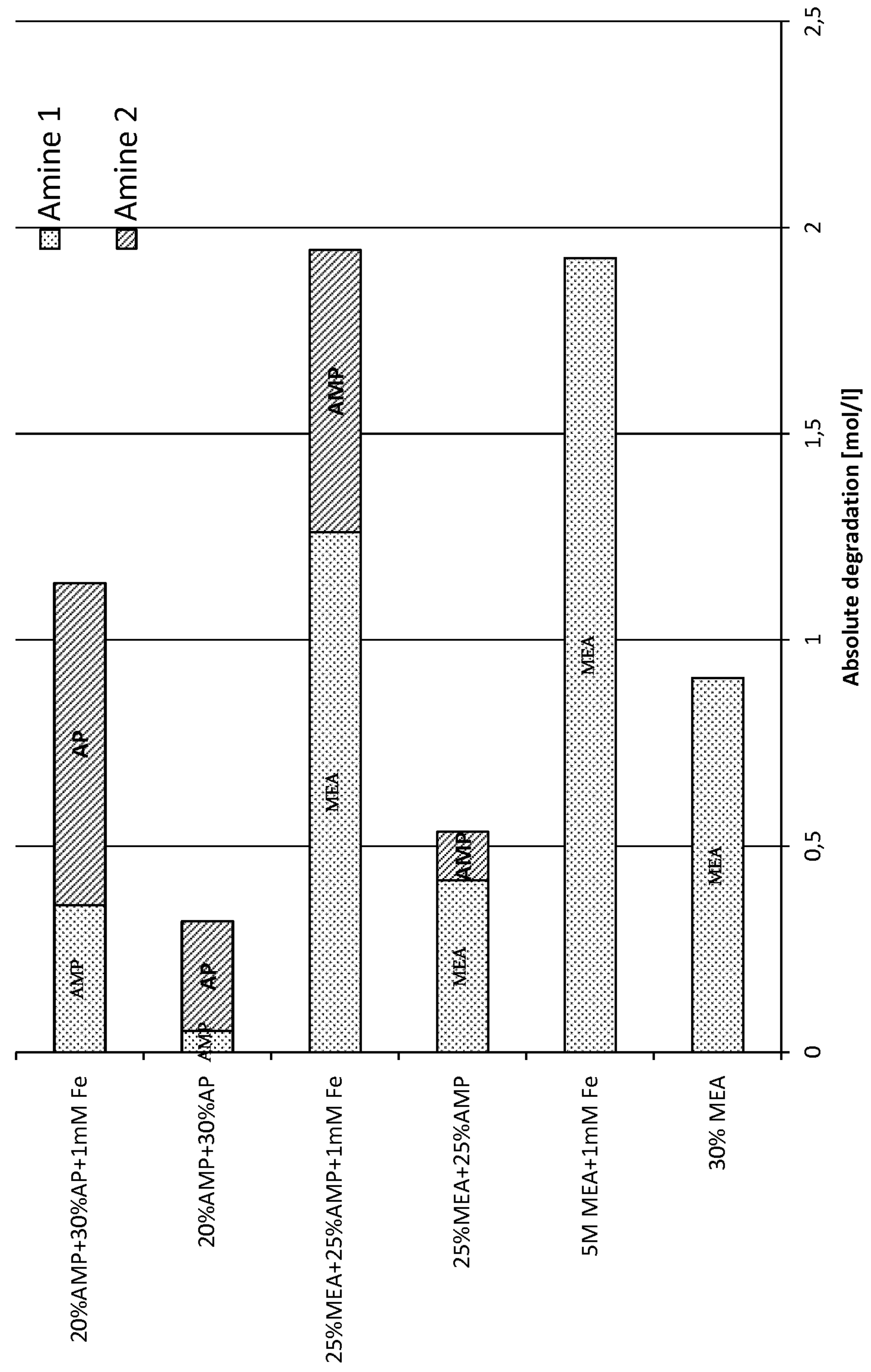
Amine 1
Amine 2
20%AMP+30%AP+1mM Fe
20%AMP+30%AP
25%MEA+25%AMP+1mM Fe
25%MEA+25%AMP
5M MEA+1mM Fe
30% MEA
AMP
AP
AMP
AP
MEA
AMP
MEA
AMP
MEA
MEA
0
0,5
1
1,5
2
2,5
Absolute degradation [mol/l]

Fig. 3

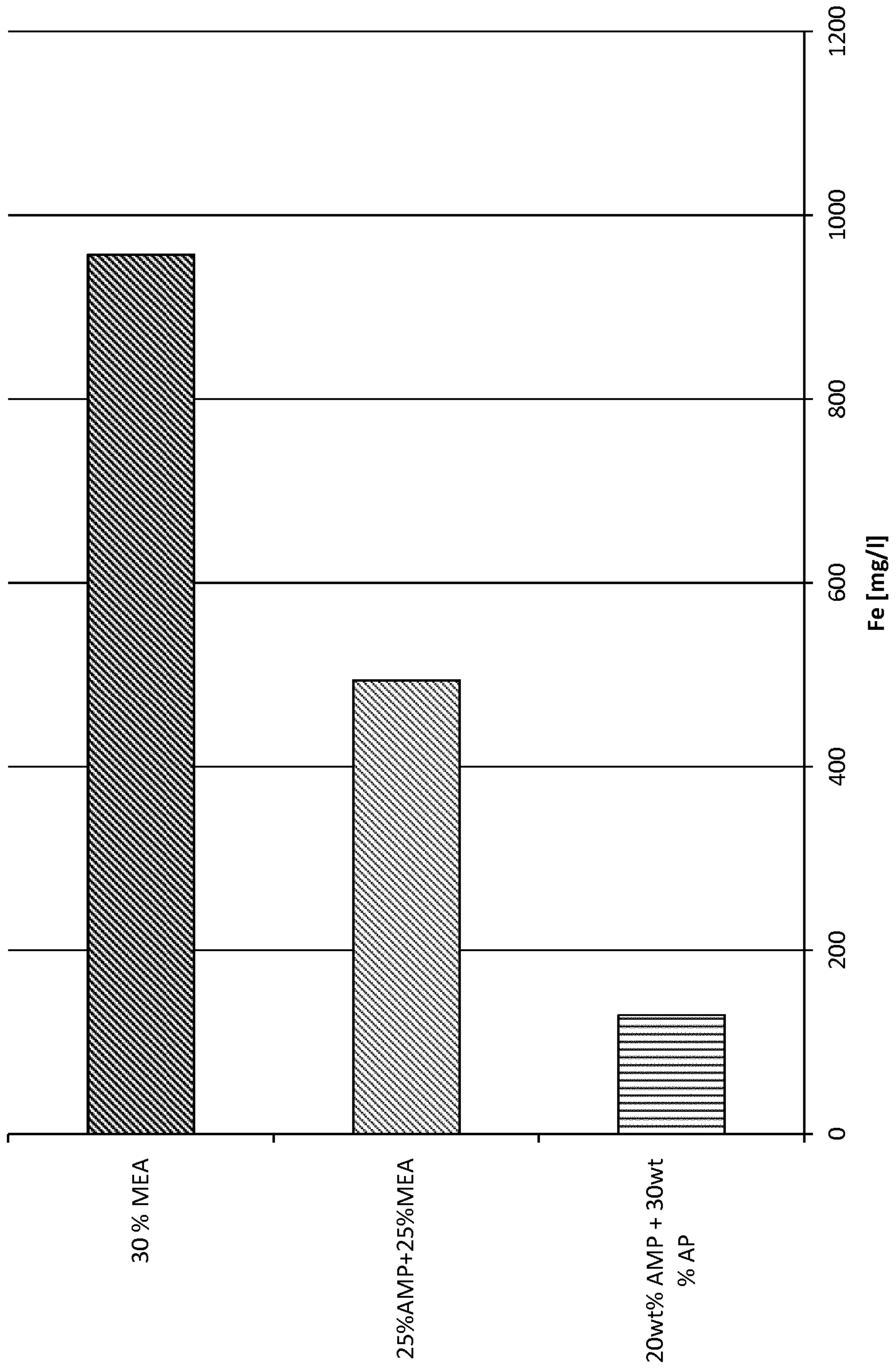
0
200
400
600
800
1000
1200
Fe [mg/l]
30 % MEA
25%AMP+25%MEA
20wt% AMP + 30wt % AP

Fig. 4

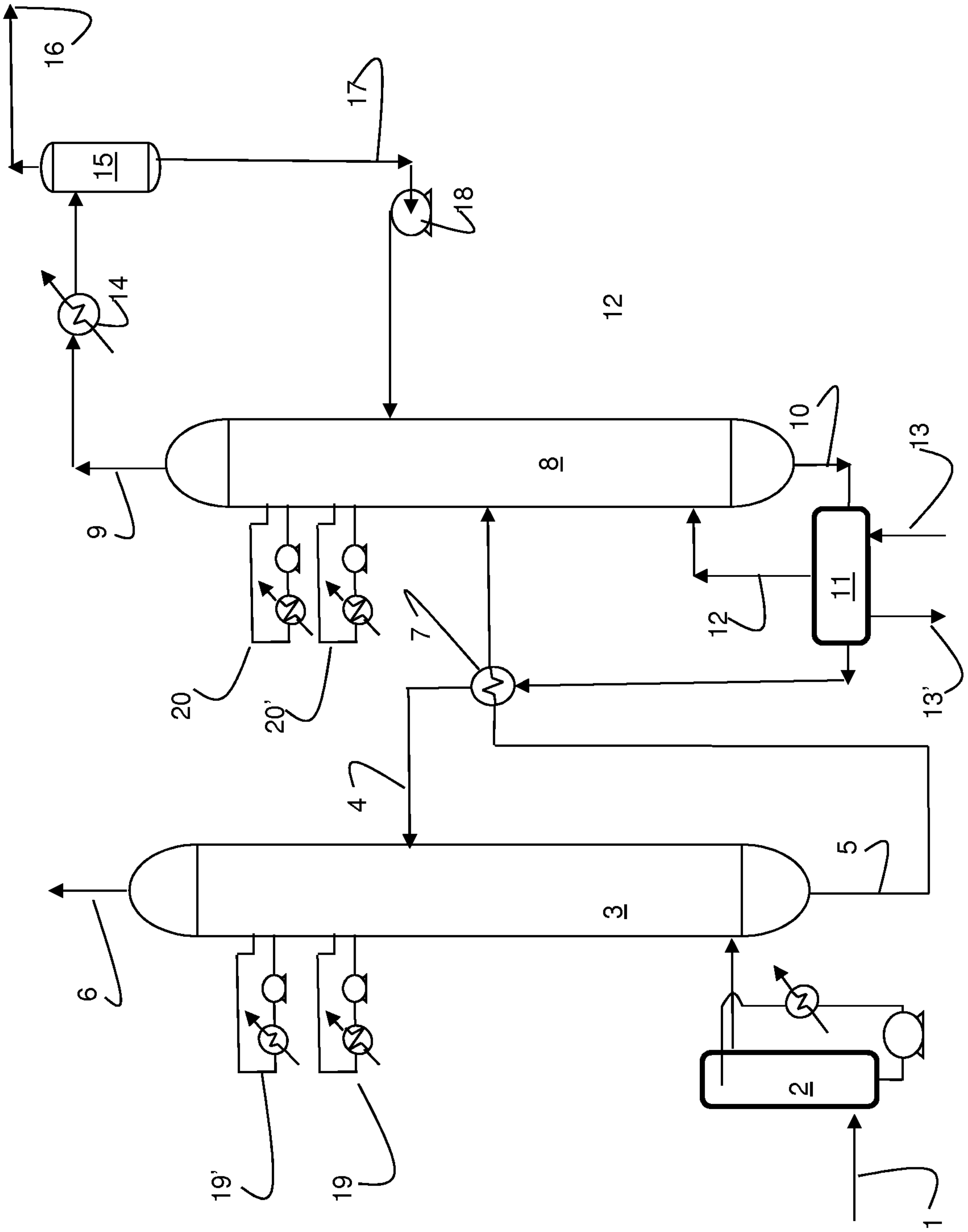

Fig. 5

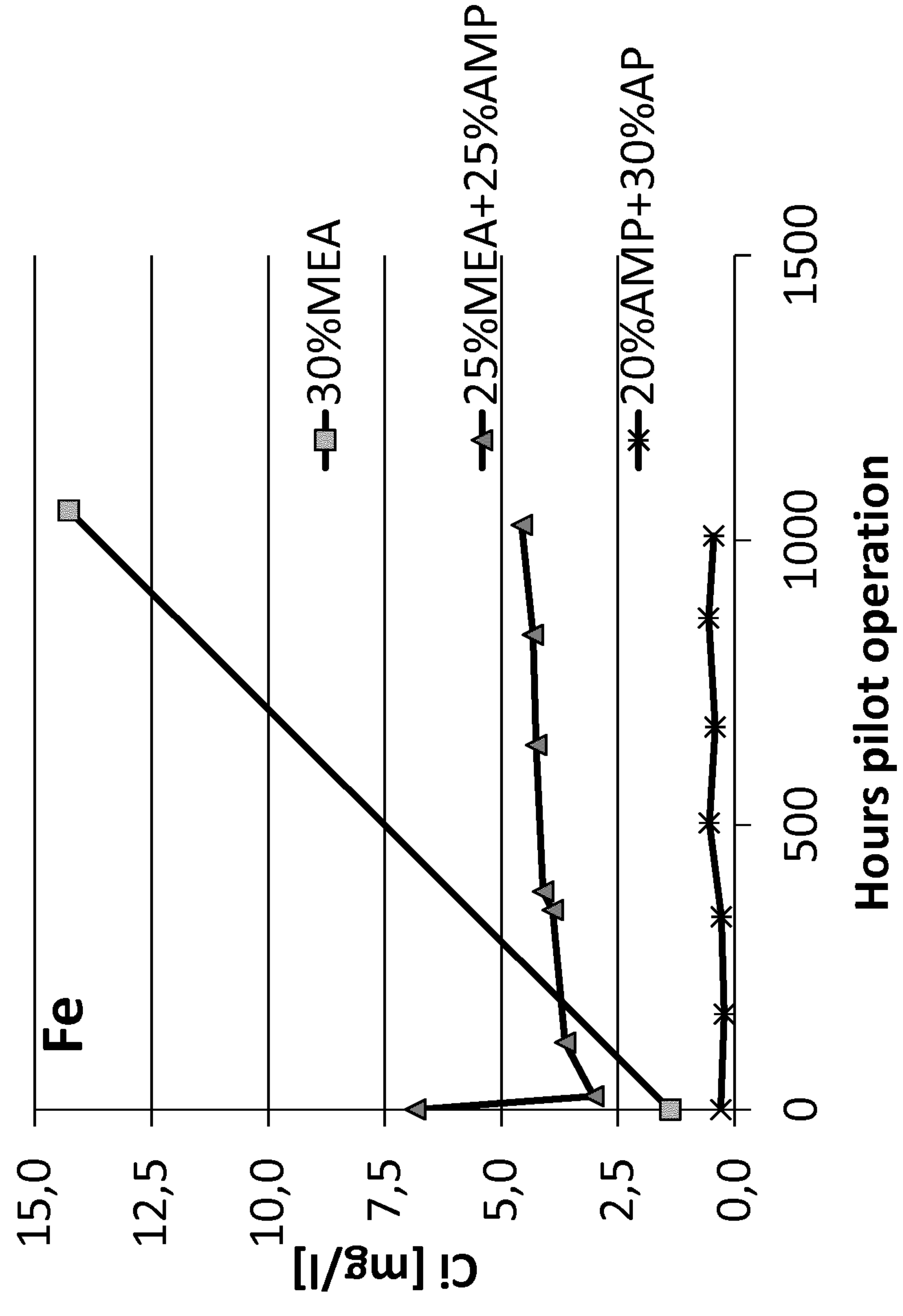
Fe
Ci [mg/l]
15,0
12,5
10,0
7,5
5,0
2,5
0,0
0
500
1000
1500
Hours pilot operation
30%MEA
25%MEA+25%AMP
20%AMP+30%AP

Fig. 6

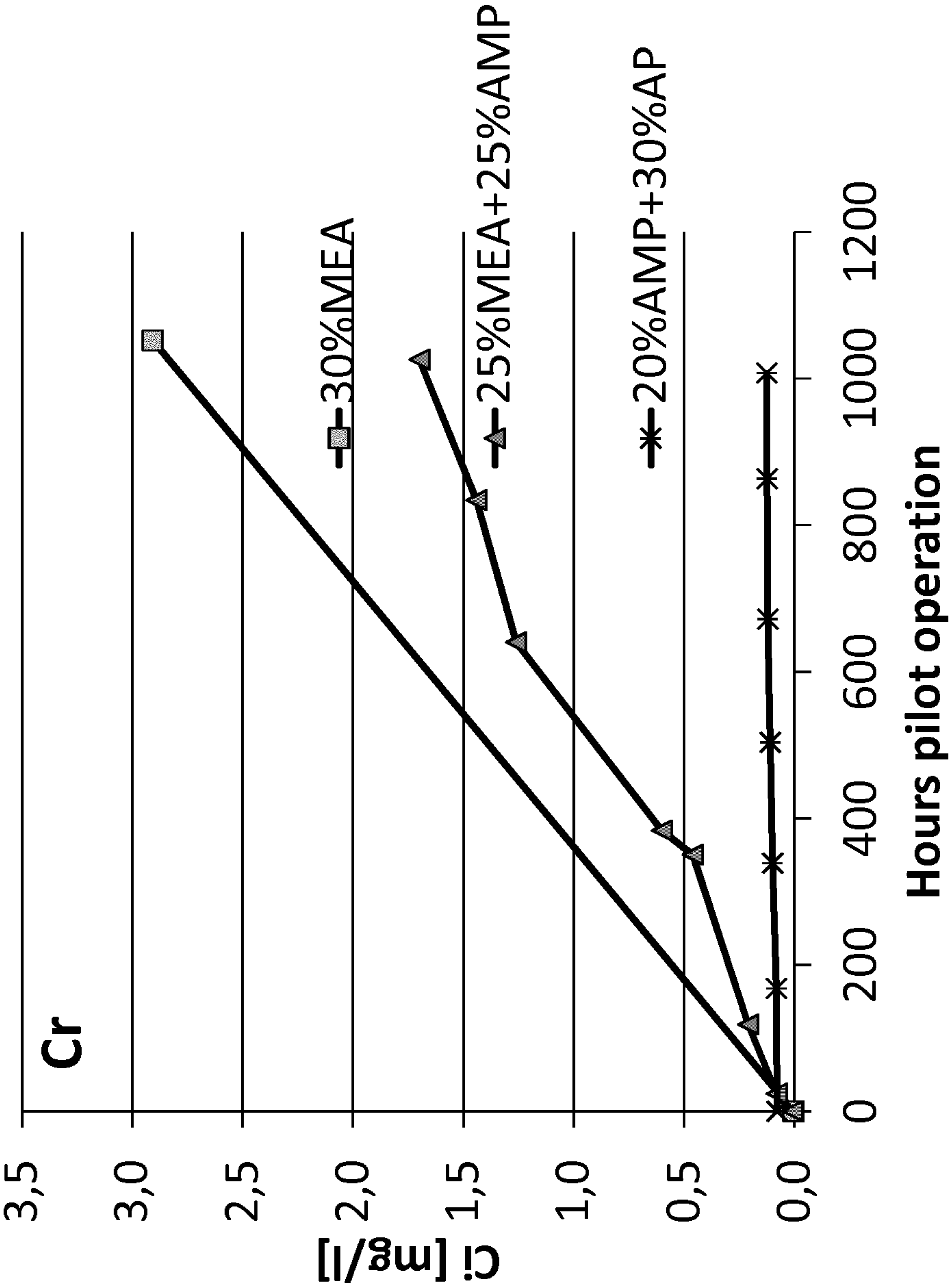
Cr
Ci [mg/l]
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
0
200
400
600
800
1000
1200
Hours pilot operation
30%MEA
25%MEA+25%AMP
20%AMP+30%AP

Fig. 7

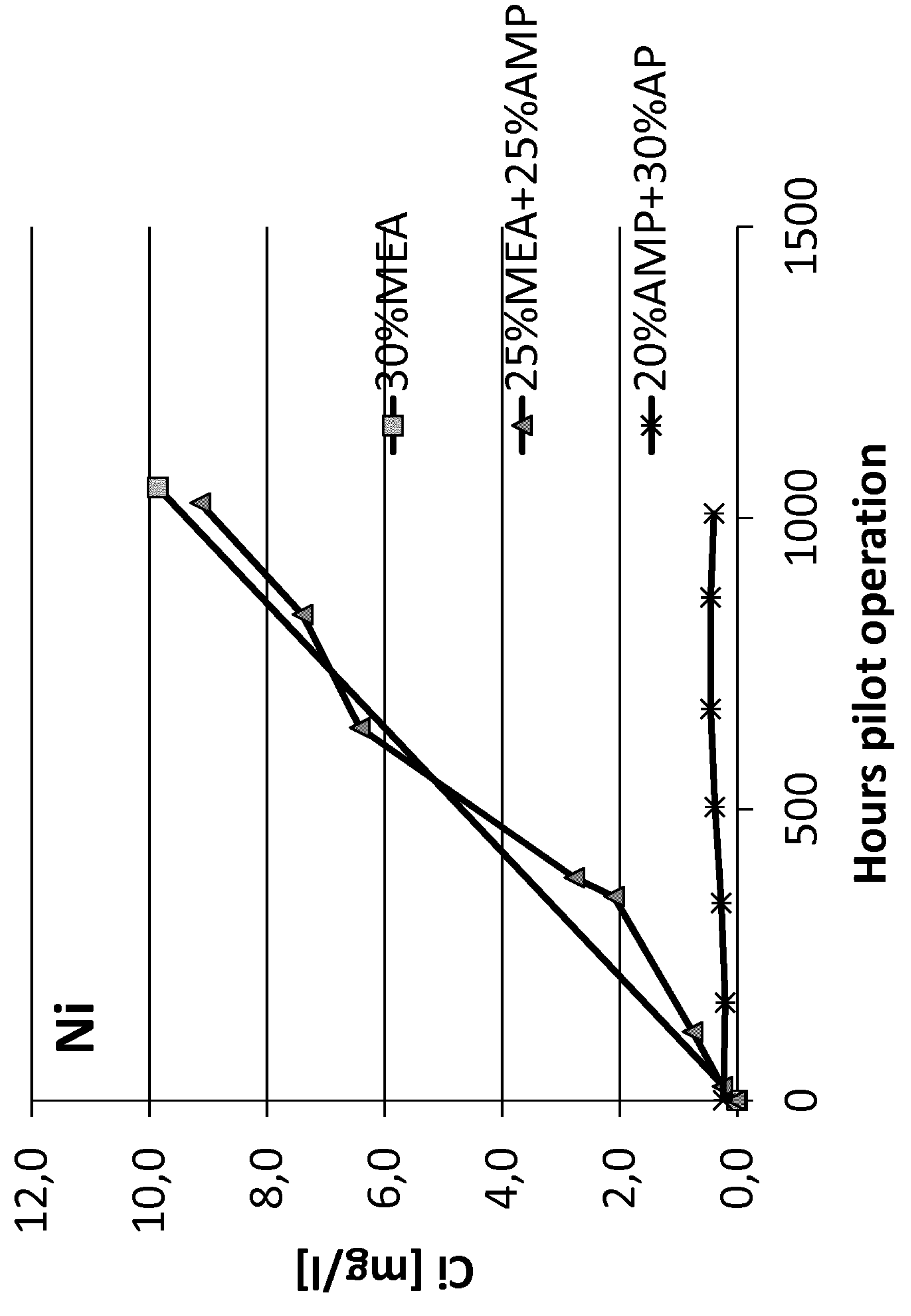
Ni
Ci [mg/l]
12,0
10,0
8,0
6,0
4,0
2,0
0,0
0
500
1000
1500
Hours pilot operation
30%MEA
25%MEA+25%AMP
20%AMP+30%AP

Fig. 8

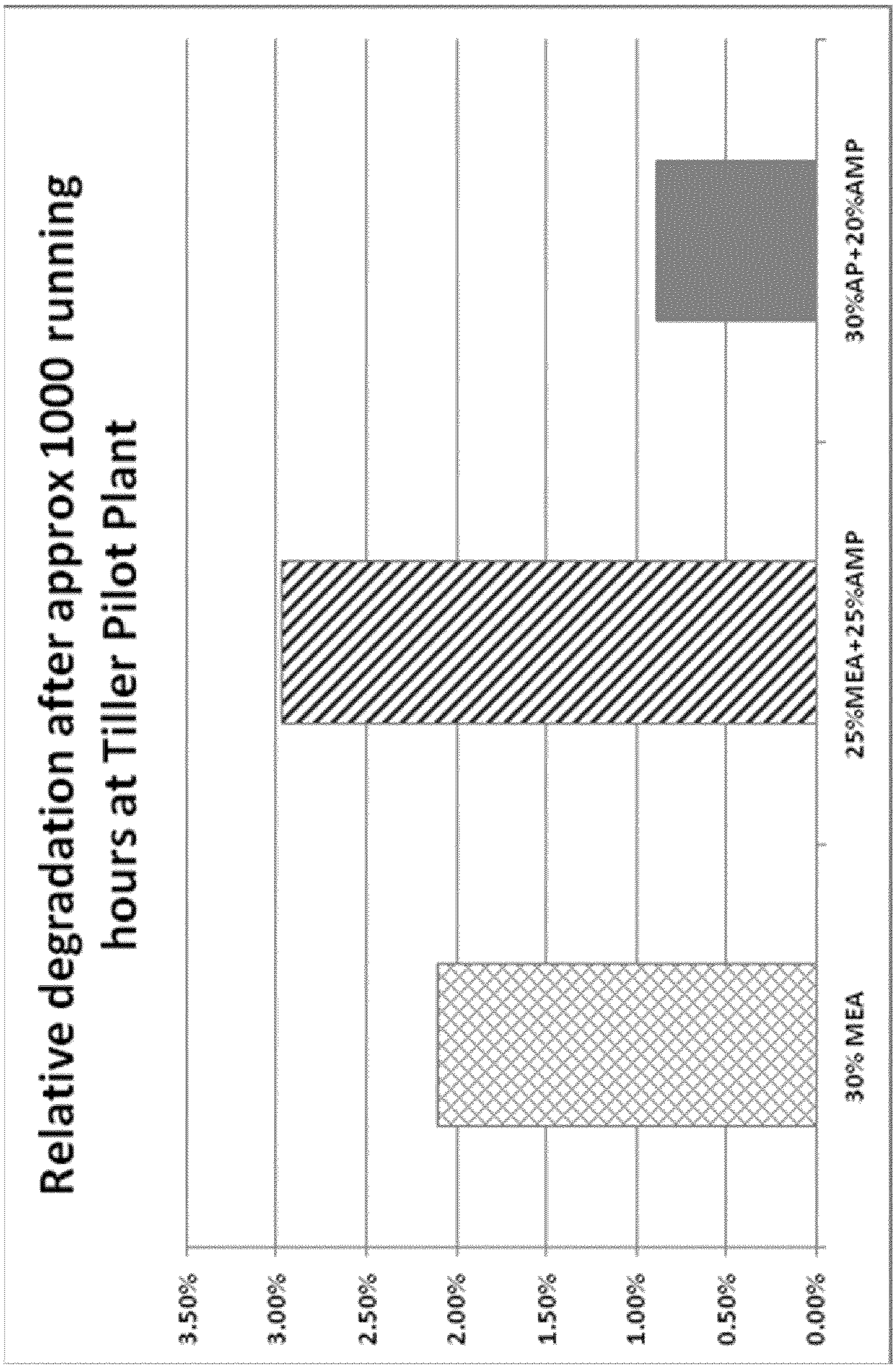
Relative degradation after approx 1000 running hours at Tiller Pilot Plant
3.50%
3.00%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
30% MEA
25%MEA+25%AMP
30%AP+20%AMP

Fig. 9

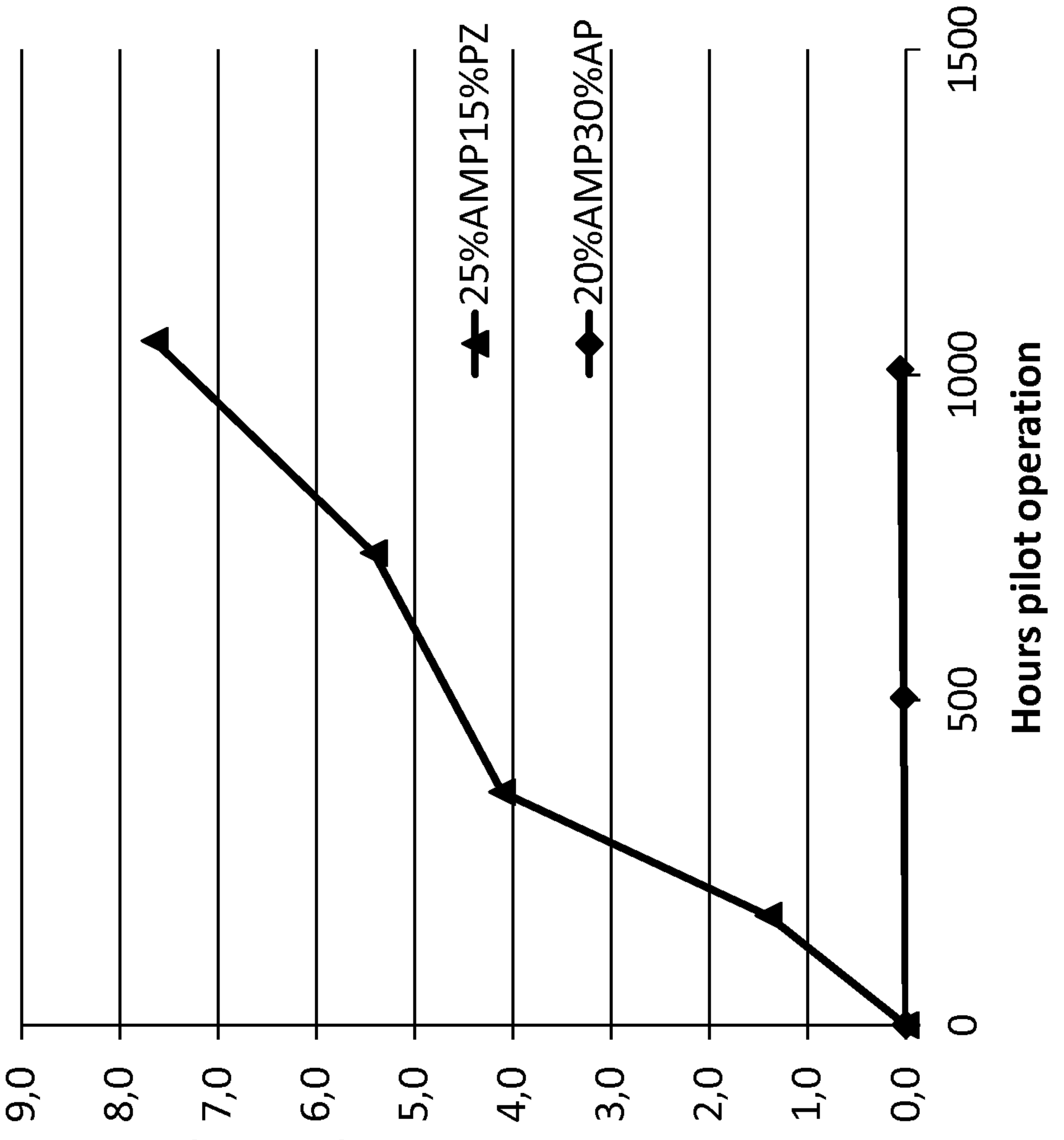
Total nitrosamine (mmol/l)
9,0
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
0
500
1000
1500
Hours pilot operation
25%AMP15%PZ
20%AMP30%AP

Fig. 10

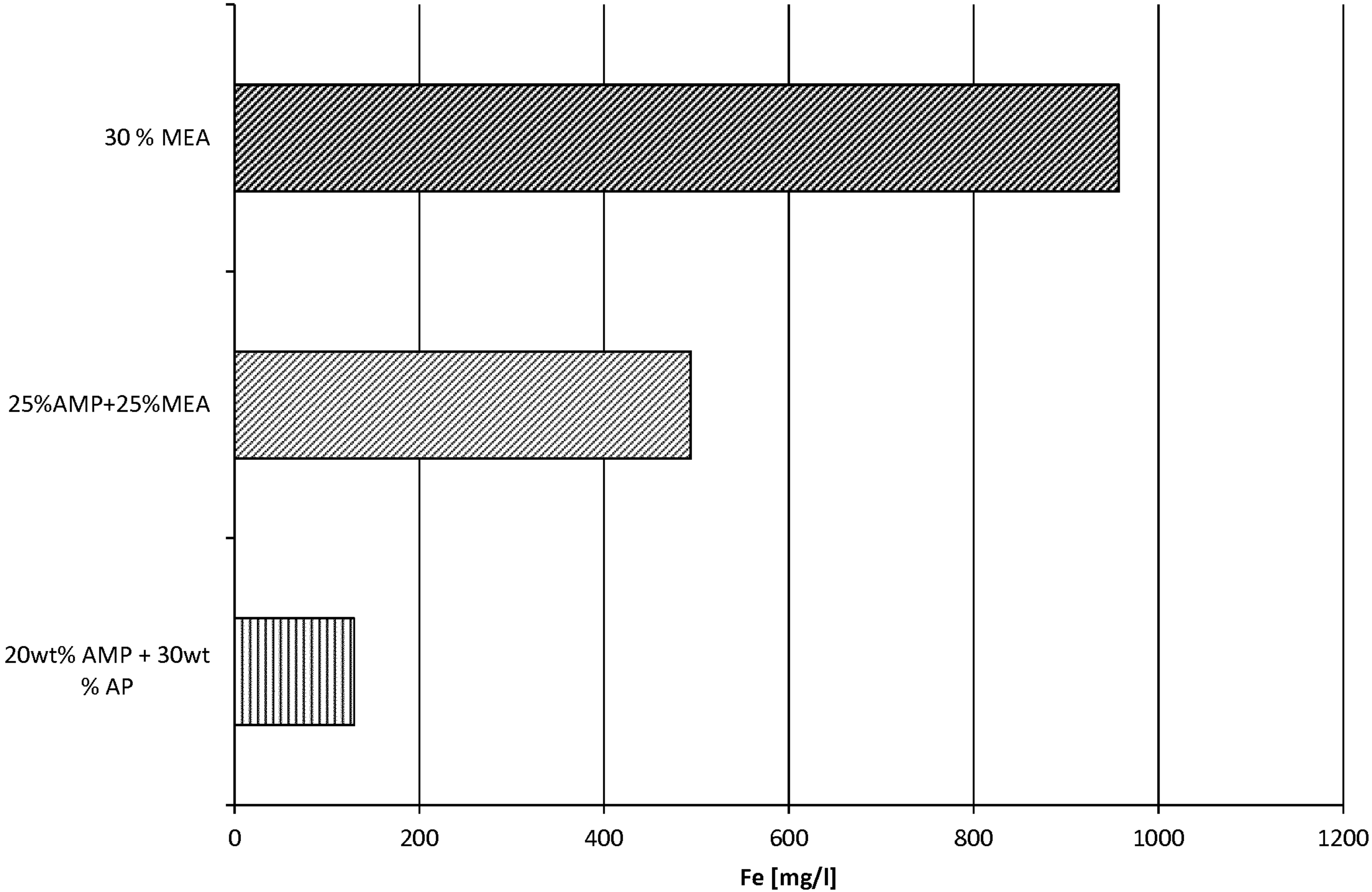
30 % MEA
25%AMP+25%MEA
20wt% AMP + 30wt % AP
0
200
400
600
800
1000
1200
Fe [mg/l]

Fig. 4