IS BUFFERING THE ANSWER TO OVERCOME THE FLUCTUATION OF INDUSTRIAL EFFLUENT QUALITY AT AN UF-RO PLANT?

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ABSTRACT
The performance of the UF-RO plant depends highly on the quality of the effluent. In this case the effluent quality varies a lot and therefore not always suitable for (re)use. Sometimes other water sources have to be used, like drinking water. However the intake costs of drinking water makes the UF-RO plant economically less attractive. For this reason an investigation is started on the impact of a water buffer, stabilization pond on the industrial effluent water quality. This paper evaluates the water quality and the performance of the UF-RO plant fed by industrial effluent after buffering in a stabilization pond.
The concentration of foulants decreases significantly during buffering in a stabilization pond. This is in contrast with the results of SUR measurements. However due to the pretreatment well filterable UF feedwater could be obtained. The fouling rate of the RO unit was almost similar for both the stabilized and the unstabilized effluent. In general it seems that the temperature and presence of algae are the main disadvantages of effluent water buffering in a pond and not expected effluent water fouling properties. The successful UF-RO processing of algae in effluent feed water should be further investigated. In the full scale UF-RO application the water temperature and the linked water viscosity will be a problem in winter time when temperature drops to below 10°C, which can not be compensated in the UF-RO systems.

KEYWORDS
Pond; reuse; SUR; UF-RO; wwtp effluent

INTRODUCTION
The reclamation and reuse of industrial wastewater has been practiced for several years all over the world in varying degrees of success. Driving forces depends on local circumstances but are mainly more stringent sewer discharge limits, increasing water costs and regional water scarcity. A proven and increasingly accepted technology for both reuse and direct discharge applications is membrane technology. Especially, ultrafiltration (UF) membranes are becoming the standard pretreatment solution upstream of reverse osmosis membrane (RO) plants for wastewater reclamation, presenting an optimal combination for the removal of suspended and dissolved materials in the production of demineralised industrial process water (Buer., et al., 2007). In a recent survey of RO plants world-wide, more than 78% of the wastewater reclamation plants

that were surveyed used low pressure membranes as a pretreatment for the RO process (Burbano et al., 2007).

In spite of the expanding market of the membrane technology there are still constraints for further application of this technology. One of the key constraints is membrane fouling (Amy, 2007). A general classification of membrane fouling includes colloidal fouling, biofouling, organic fouling and inorganic fouling (scaling). The major fouling for both UF and RO is organic fouling (Amy, 2007). However, the classification of organic fouling overlaps those of colloidal fouling and biofouling. Organic fouling includes macromolecules which are also organic colloids. Organic colloids are mainly responsible for organic fouling of UF (Te Poele, 2005). Biofouling, the main organic fouling of RO, can be considered as a biotic form of organic fouling while organic matter derived from microbially-derived cellular debris can be considered as an abiotic form of fouling (Amy, 2007).

During membrane filtration the fouling can be controlled by cleaning the membranes periodically. Cleaning can be performed either hydraulically, mechanically, chemically or by electrical cleaning. Only hydraulically and chemically cleaning will be described in this paper. Depending on the configuration the mainly applied hydraulically cleanings are the back flush (the flow changed to the opposite direction) and the forward flush (complete cross flow a high flow rates). Hydraulically cleaning is not applied during RO. The fouling that retains after a hydraulic cleaning (irreversible fouling) can be removed by chemically cleaning. The chemical cleaning is the only applied cleaning during RO. During UF both methods are used.

Besides cleaning, the fouling of the membranes can be controlled by pretreatment. In this paper the UF serves as a pretreatment for the RO. The UF unit removes particulate (organic) matter, which results in a stable performance of the RO. Also for an UF mostly a pretreatment step is placed to enhance the filtration rate and to decrease the fouling rate. Another purpose of pretreatment is to minimize the effect of quality variations. For domestic wastewater treatment plant (wwtp) effluent varies during night and day, winter and summer and dry or rainy weather. Industrial effluent has typical effluent water quality depending on the industrial production processes and the unique variation in production will determine the effluent composition.

The described UF-RO plant has a large fluctuation and variation in effluent water composition. Many reasons can explain the variation e.g. poor operation of the wwtp, discontinues discharge from the industrial batch processes, complex biodegradable batches (new products), wastewater coming from incidental industrial cleaning processes, etc. Unfortunately, the currently applied pretreatment steps are not able to minimize the effect of the varying quality during ‘bad quality’. Therefore an extra pretreatment step (stabilization pond) is implemented to stabilize the quality during those events. This paper will evaluate the performance of the UF-RO plant during the intake of industrial effluent after buffering in the stabilization pond.

UF-RO PLANT AND STABILIZATION POND

UF-RO plant

The UF-RO plant in Sas van Gent (The Netherlands) is in operating by Evides Industriewater and produces demi water from industrial effluent of a foods producing factory. The wastewater treatment plant of this factory consists of an anaerobic (UASB reactor) and an oxidation ditch. After final sedimentation in a secondary clarifier the effluent is transported to the UF-RO plant. The average quality of the industrial effluent measured by the operators is shown in table 1.

Table 1. The average industrial effluent quality of 2006.

Parameter	Unit	Concentration
Temperature	°C	32
pH	-	8.3
Suspended solids (SS)	mg/l	12.2
Turbidity	NTU	23.1
Electronic conductivity (EC)	µs/cm	5,090

The industrial effluent first passes a dual media filtration unit containing anthracite and sand. $FeCl_3$ (2.5 mg/l) is dosed inline to the feed water and flocculated above and in the filter bed. After the dual media filter again $FeCl_3$ (1 mg/l) is dosed in order to increase the performance of the ultrafiltration units. Beside the $FeCl_3$ also sodiumhypochlorite is dosed to prevent biological growth. The total UF plant consists of 4 UF units with a total membrane area of 3,120 m^2. The UF plant feeds a RO membrane plant for further water polishing. The UF permeate is desalinated the permeate two steps (figure 1). The concentrate of the RO1 is discharged to the surface water and the permeate of RO1 is fed to RO2 after degassing. Before RO1 antiscalant and acid are dosed to prevent scaling.

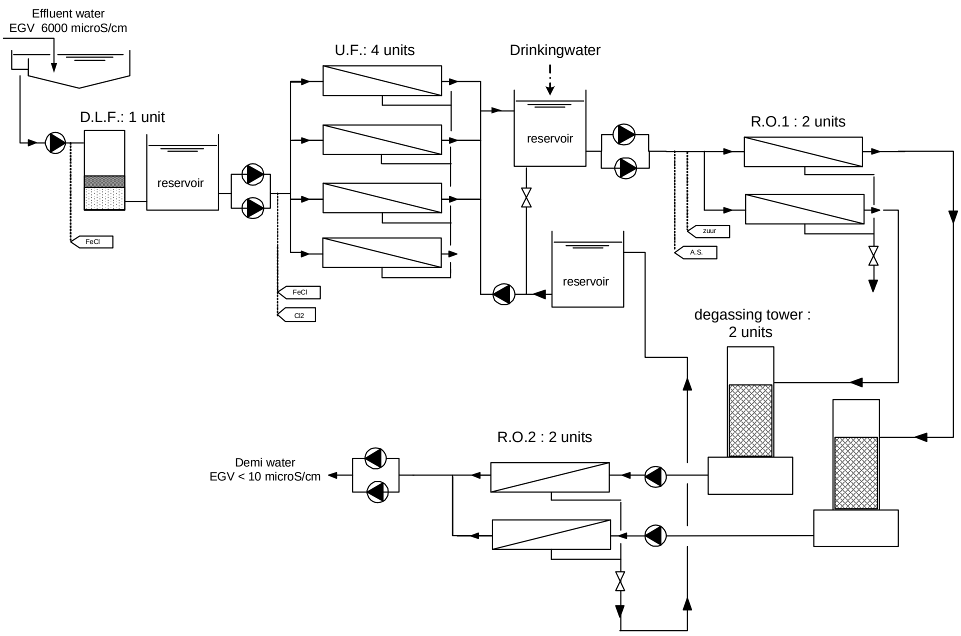

Figure 1. Process flow diagram of UF-RO plant.

Stabilization pond

Normally the stabilization pond (figure 2) is used to stabilize the residual part of the industrial effluent before it will be discharged to the surface water. During the experiment the residence time of the industrial effluent is 2 to 3 days. Because of the systems design (the water intake criteria) of the UF-RO plant a heat exchanger is used to stabilize the feed water temperature above a temperature of 20°C.

Figure 2. Impression of stabilization pond and pump to transport buffered effluent to the UF-RO plant.

EXPERIMENTAL SETUP

During six weeks (August, 31 – October, 12 2006) the UF-RO plant was fed by industrial after pond passage. During this period the filterability and quality of both industrial effluent after secondary clarifier and after pond passage are monitored. The performance of the UF and RO are monitored as well during this period.

Filterability and water quality

The filterability of the industrial effluent after secondary clarifier and after pond passage was monitored approximately four times a week. To measure the filterability the Specific Ultrafiltration Resistance (SUR) parameter is used. This parameter developed by Roorda (2004) provides useful information about the filterability within a short time (30 minutes) and can be measured with a simple laboratory set-up (figure 3). With the SUR value a rough indication of the performance of an UF plant can be predicted (Janssen et al., 2007).

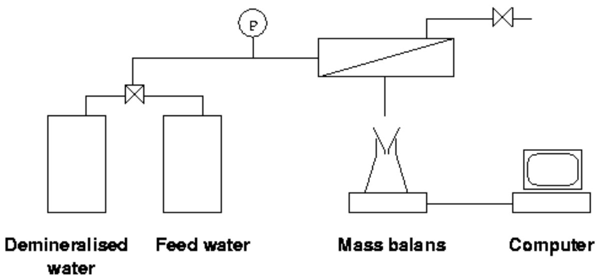

Figure 3. Schematic drawing of the laboratory test set-up.

Also the effect of pretreatment was investigated with SUR measurements. The filterability before the first ferric chloride dosing and after the second ferric chloride dosing (feedwater UF) was measured four times a week during the period of study.
Besides the filterability the water quality of the two different sources was monitored. The concentration of extracellular polymeric substances (EPS), humic acids, colour and dissolved organic carbon (DOC) were analysed. These parameters are defined as the major foulants of membranes during ultrafiltration (Te Poele, 2005).

Performance of ultrafiltration

The condition of the UF membranes of one UF unit was determined during the experimental period (effluent after pond passage) and after the experimental period (effluent after pond passage). To investigate the condition of the membranes the relation between the SUR values of the UF feed water and the TMP increase of one UF unit was determined. From previous research (Janssen et al., 2007) it is known that this relation is linked with the condition (fouling) of the membranes. Fouled membranes present a higher TMP increase compared to clean membranes with the SUR value of feedwater. Data of the UF unit was collected from the control computer. With these data the slope of a single filtration cycle (20 minutes) was measured at the same time as a SUR measurement (Figure 4). The numbers were only used when the R^2 of the line was ≥ 0.7. Besides, the increase of TMP was normalised for temperature and flux. The nominal temperature and flux were respectively 20 °C and 60 l/m^{2}h.

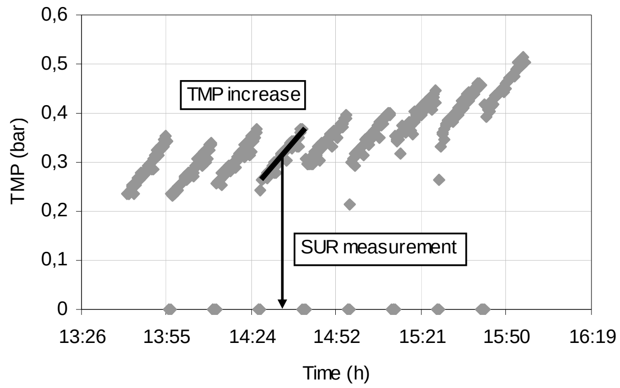

Figure 4. Example of filtration cycles during ultrafiltration and the moment that SUR measurements are performed of the UF feed water.

Performance Reverses Osmosis

The performance of the RO membranes of one RO unit (RO1A) is also determined. The process data were collected before, during and after experimental period of the RO1 units. The water flux as Mass Transfer Coefficient (MTC) and Normalized Pressure Drop (NPD) were calculated at 25 °C. Via this information the effect of the different pretreatment schemes on the RO performance can be determined.

RESULTS

Water quality and filterability

In table 2 the average concentrations of the quality parameters of both sources during this study are presented.

Table 2. Average concentration of foulants of the effluent from clarifier and pond during August, 31 till October, 12.

Foulant	Unit	Clarifier (average)	Pond (average)
Proteins	mg/l	32,7	18,7
Polysacharides	mg/l	7,5	7,3
EPS	mg/l	40,2	26,1
DOC	mg/l	23,9	22,7
Humic Acids	cm^{-1}	0,52	0,43
Colour	mg Pt/l	87,0	63,9

Table 2 shows a varying composition for the different substances. Opposed to the polysaccharide concentration the concentration of proteins is significantly lowered by pond passage. The amount of EPS is also lowered but this is mainly caused by the decrease of proteins. The humic acids and colour concentrations show the same trend as proteins and EPS. However, the DOC concentration did not decrease during the pond passage. A clear explanation for this contradiction is difficult but probably the presence of algae in the pond plays a role. The algae were clearly visible in the water. During DOC analyses all dissolved carbon (including possible rests and products of algae) is measured instead of certain parts of DOC.

Nevertheless, the decrease of proteins is and interesting observation in this study. From previous research it is well known that proteins are mainly responsible for the long term membrane fouling (Te Poele, 2005).

In figure 5 the SUR values of the effluent from the stabilization pond and secondary clarifier are presented. Only during the period of this study (August, 31 – October, 12 2006), when the UF was fed with effluent from the stabilization pond both sources were sampled.

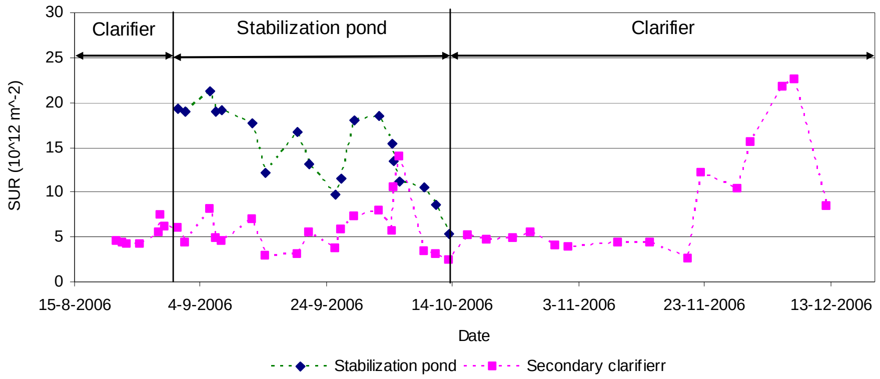

Figure 5 SUR values of the effluent from the secondary clarifier and stabilization pond.

The SUR values of the effluent after pond passage are significantly higher compared to effluent after the clarifier. The SUR values of effluent after the clarifier were almost always distinctly below 10 × 10^{12} m^{-2} during the study period. Unfortunately, the SUR values of the effluent after pond passage are in the range of 13 - 20 × 10^{12} m^{-2} most of the time. It is predictable that the presence of algae is responsible for the difference in SUR values. During a few measurements relatively high concentrations of chlorofyl were observed (Trampé, 2007). The concentrations were in the range of 90-1,420 µg/l (chlorofyl-a).

Figure 5 shows high SUR peaks (December, 5-7) when the UF was fed with secondary clarifier effluent. Unfortunately, this peaks were not noticed during the experimental period. It seems that during the experimental period the wwtp was working well.

In figure 6 the effect of the pretreatment steps (coagulation – filtration – coagulation) on the filterability of industrial effluent is shown. As shown in figure 6 only during the experimental period industrial after pond passage. Before and after this period the pretreatment and UF were fed with secondary clarifier effluent.

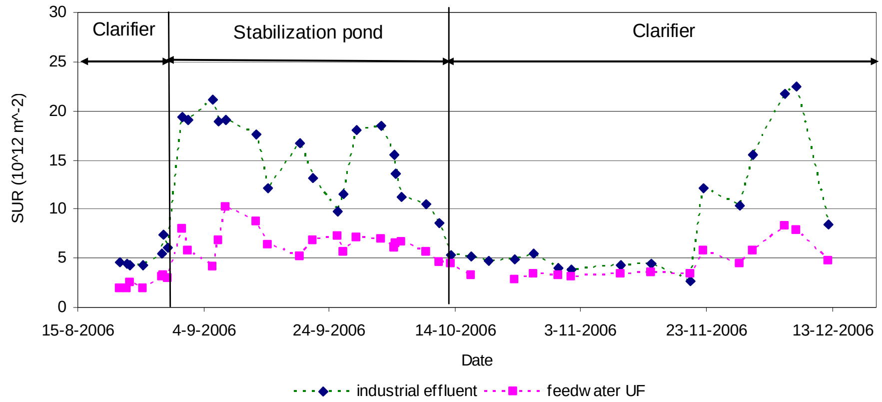

Figure 6. SUR values of the industrial effluent from the stabilization pond for and after pretreatment.

The filterability of industrial effluent after pond passage improved significantly by pre treatment. Considering the definition of well filterable water (SUR < 10×10^{12} m^{-2}) it seems that industrial effluent after buffering in a pond and pre treatment is suitable for reuse. But, it should be considered that the SUR values of the effluent after the clarifier were relatively low during the experimental period. Normally, the variation of filterability is higher. This can also be noticed form figure 6. After a period of well filterable effluent (October, 14 – November, 20) the SUR values increased suddenly.

Performance Ultrafiltration

Figure 7 shows the relation between SUR and TMP increase during one filtration cycle of one UF unit during filtration of industrial effluent after secondary clarifier and stabilization pond passage.

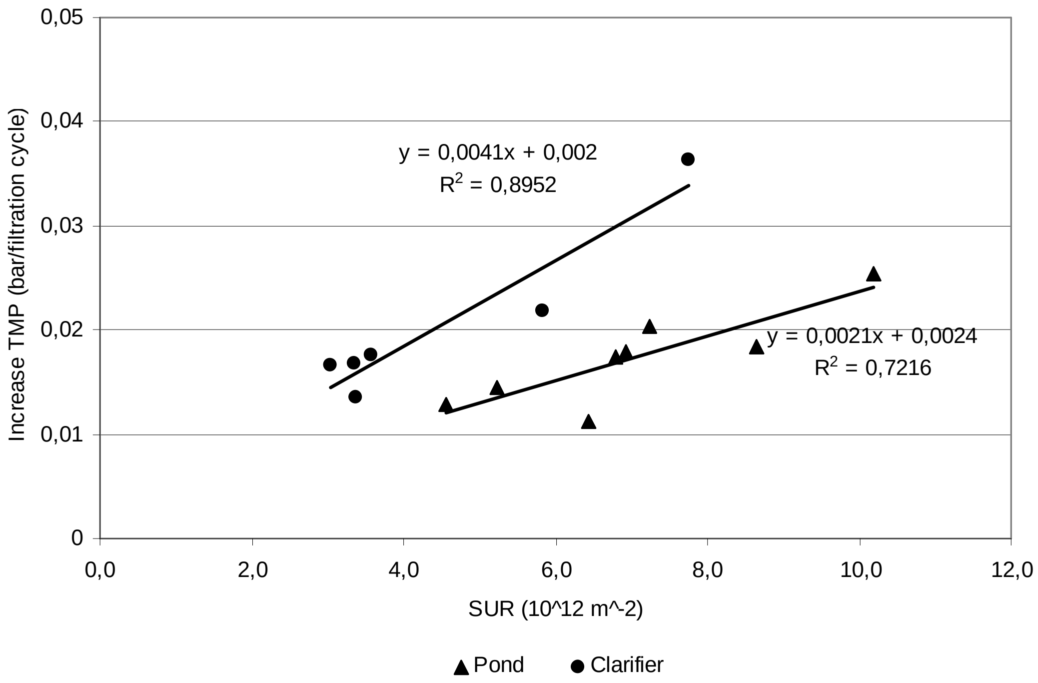

Figure 7. Relation between SUR values of feedwater UF and TMP increase during one filtration cycle of one UF unit.

A different relation can be observed in figure 7. The increase of TMP during ultrafiltration of effluent after the secondary clarifier is higher compared to effluent after the stabilization pond. At SUR values of 8 – 10 × 10 m^{-12} the difference in increase of TMP is almost two times higher. Probably the amount of foulants plays a role. The amount of foulants was significantly less in the effluent after pond passage (table 2). However, there is no consensus about the relation between foulants and filterability (Te Poele, 2005 and Amy, 2007).

Another explanation could be a retained fouling layer on the UF membranes after they were fed with effluent of the pond. Extra fouling needs extra pressure to filtrate the feedwater and therefore higher increase of TMP.

Performance Reverses Osmosis

In figure 8 the Normalized Pressure Drop (NPD) and the temperature of the feedwater of RO1A are plotted. The abbreviation CIP in the figure stands for Chemical In Place. During a CIP the RO membranes are cleaned with different cleaning agents to remove biofouling and scaling.

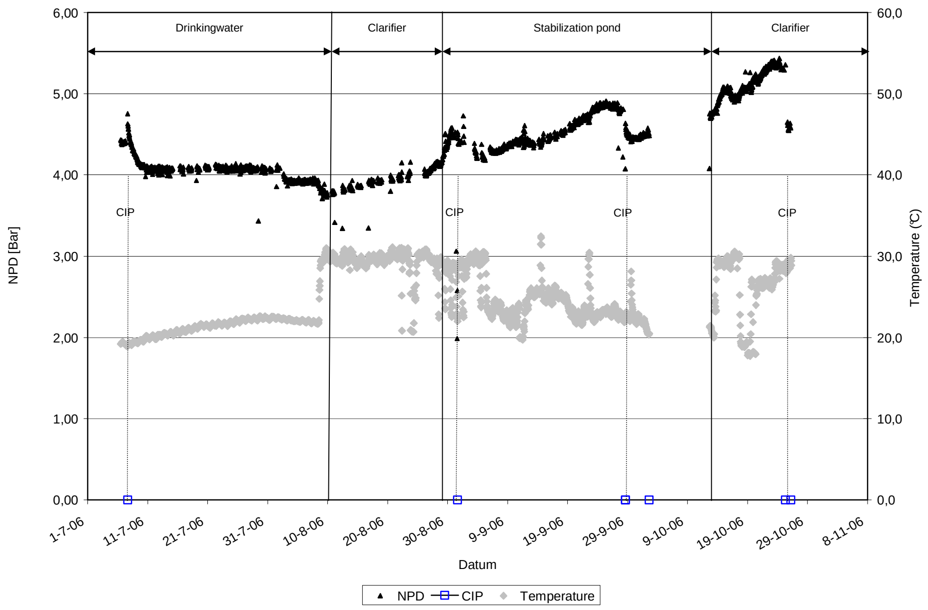

Figure 8. The NPD and the temperature of RO1A.

The temperature of the RO feedwater is significantly lower during the intake of pond effluent. In the stabilization pond the effluent water is lowered in temperature. Therefore a heat exchanger was required to keep the temperature of the feedwater above 20 °C. Probably this will give problems in wintertime.

The (bio)fouling rate (increase of NPD per time) during the intake of effluent from the clarifier and pond are almost similar. During the experimental period a lower (bio)fouling rate was expected due to the lower EPS concentrations in the feedwater. From literature it is known that proteins and polysaccharides play a role in the formation of biofouling (Amy, 2007).

CONCLUSIONS

The concentration of foulants decreases significantly during buffering in a stabilization pond. This is in contrast with the results of SUR measurements. It is obvious that the presence of algae in the pond explains this contradiction. A reason for the presence of algae could be the residence time (2 to 3 days) in the pond. A shorter residence time (± 1 day) will probably result better SUR values. Roorda (2004) observed well filterable effluent in Tilburg - Noord (The Netherlands) with a residence time of 1 day.

The SUR values of the effluent after pond passage are significantly lowered by the different pretreatment steps. Most of the time the feedwater of the UF was good filterable.

Effluent from the stabilization pond after pretreatment resulted in less increase of TMP compared to clarifier effluent. Probably the amount of foulants are responsible for this difference. The fouling ratio of the RO unit before and during the experiment is almost the same. The altered effluent water composition in combination with present (accumulated) fouling layer on the RO membranes doesn't have impact on reducing the NPD increase.

The temperature and presence of algae play an important role in this research. For RO the minimum temperature is 20 °C. It seems this will give problems during winter time. Extra energy will be needed to heat the effluent. Presence of algae should also be prevented or minimized.

In general the results of this study are not strong enough to say yes or no against buffering of effluent in a pond. For example no real 'bad quality' event occurs during the period. Therefore, to make this conclusion stronger the research should be repeated during a 'bad quality' event.

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