Replaceable Skin Layer Membranes™- Manipulating the Electric Double Layer on Colloidal Solids to create 10-fold improvement in Flux rates.

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Introduction

Figure 1:
RSL Membranes™ Bundle

Conventional low-pressure membranes (i.e. microfiltration- MF and ultrafiltration-UF) are a common water treatment process Conventional membranes consist of an affixed skin layer that has a pore size smaller than the solids being separated. The common problem with conventional membranes is the fouling of the skin layer requiring frequent backwash pulses . When the skin layer does become fouled, aggressive chemical cleaning is necessary. Unfortunately, the skin layer never recovers to it original condition and eventually deterioration requires the entire membrane to be replaced. However, one of the benefits of conventional membranes is consistent and high quality permeate water quality.

An option to conventional membranes is dynamic membranes. Dynamic membranes rely on the placement of a powder precoat (i.e. diamataceous earth) and/or the placement of solids inherent with the liquid being filtered, on a porous substrate. This placement of solids on the porous substrate causes a bridging to create a small pore size for filtration. The more the bridging of solids, the smaller the pore size. The permeate from dynamic membranes improves in quality over the length of the filtration run.

A new option, called Replaceable Skin Layer membranes (**RSL Membranes™**-patent protected) has been developed to eliminate the operational issues of conventional membranes and dynamic membranes. The **RSL membranes™** do not rely on a barrier concept for solid and colloid separation from fluids. Instead, the **RSL membranes™** rely on manipulating the electric double layer (EDL) around colloidal solids. The DLVO theory helps explain this manipulation.

Methodology

The following two third party evaluated field pilot tests assessed the RSL Membrane technology in comparison to conventional technology.

1. Comparison of the **RSL membranes™** with Veolia's silica carbide CeraMem® Membrane Systems. The conclusion was that RSL Membranes™ had a 10-fold flux advantage.
2. Comparison to conventional low-pressure membranes to separate emulsified oil in refinery waste water. The third party analysis confirmed the high flux rates combined with low TMP.

Our objective after these field trials was to prove the hypothesis that the **RSL membranes™** had significantly improved operating parameters due to manipulation of the colloids electric double layer. The key steps to proving this hypothesis were to test different powder configurations and their impact on permeate turbidity vs transmembrane pressure and filtration cycle time.

Figure 2: Refinery Coker water with emulsified oil

The powders evaluated were

1. Conventional dynamic membrane powders such as diatomaceous earth and activated alumina
2. Varying configuration of highly ionic powders. A wastewater was prepared using kaolinite clay. Four grams / 20 litres was vigorously mixed in potable water and then allowed to sit for 12 hours. The supernatant was used as the test water with a typical turbidity of 30 NTU. Duplicate measurements were taken for TMP and NTU. The flux rate was a consistent 350 lmh.

Results & Discussion

Over 150 tests were undertaken with 23 different powder formulations. It became clear that certain modifications and characteristics of the powder formulation created an improved result of transmembrane pressure (TMP) vs turbidity (NTU) over time. To explain this further, there are two typical TMP-NTU-Time curves for each of the two conventional membrane types.

For conventional **low-pressure membranes**, the typical TMP-NTU-Time curve is shown in Figure 3

Note the key characteristics of this typical plot

1. TMP rises on a linear basis. In this case, after approximately 16 minutes a backwash (BW) occurs. When the backwash occurs the TMP drops but never drops to the original new membrane TMP level. The linear increase in TMP is evidence of a thin filter cake building on the surface of the membrane skin layer.
2. Eventually a chemical enhanced backwash (CEB) is performed. The CEB provides a better recovery of the TMP than the BW pulse.
3. Once the TMP reaches 200 to 300 kpa, a clean in place (CIP) with acid and caustic washes occurs to cause the TMP to be significantly reduced but never to the level of a new membrane.
4. Turbidity remains consistent and of high quality throughout the filtration cycle.

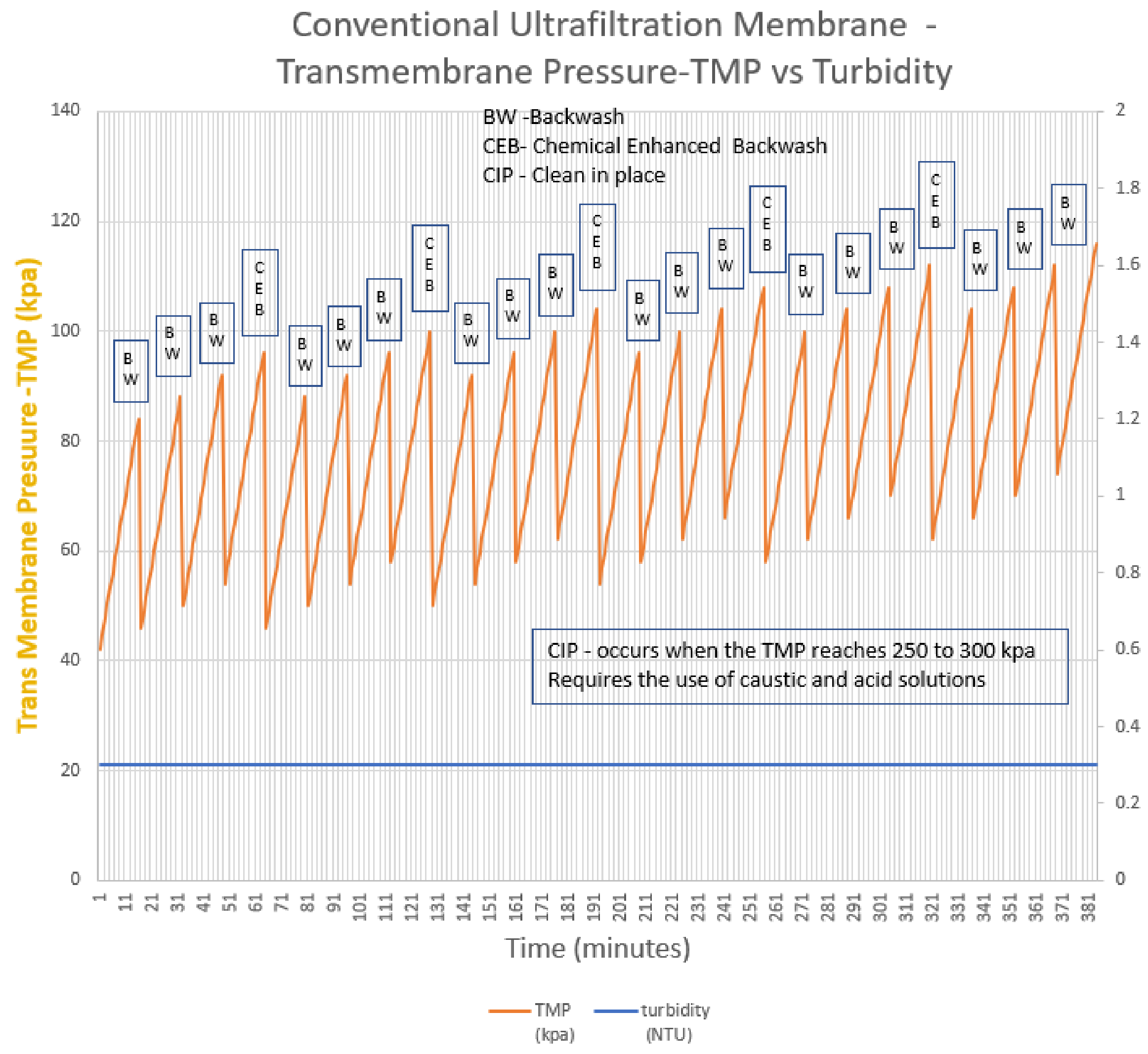

Figure 3: Typical Low-Pressure Membrane TMP-NTU-Time curve

Figure 4 provides a typical TMP-NTU-Time plot for **dynamic membranes.**

Note the key characteristics as follows

1. The TMP increases linearly as the filter cake on the dynamic membrane grows
2. The turbidity decreases as the filter cake grows

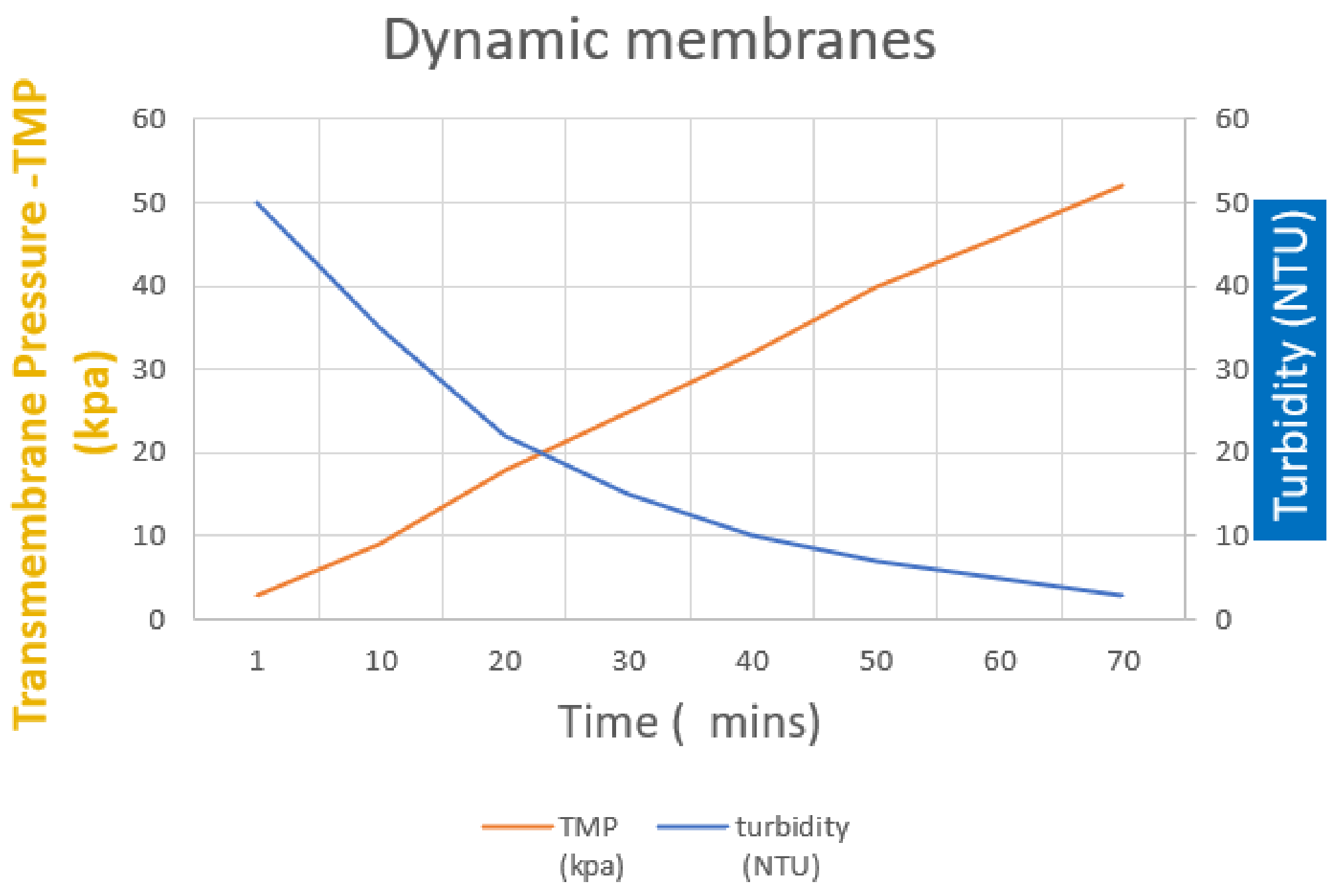

Figure 4: Typical Dynamic Membrane TMP-NTU-Time curve

Figure 5 provides a typical TMP-NTU-Time plot for **RSL membranes™**

Note the key differences in this plot versus the low-pressure and dynamic membranes.

1. The TMP is essentially zero for an extended period of time in the filtration cycle.
2. The turbidity is consistently low throughout the filtration cycle and exceptionally low (as low as 0.04 NTU) through the filtration cycle where the TMP = almost 0 kpa.
3. Backwashes are infrequent.
4. There is a burst in the TMP and then an asymptotic increase in TMP to 70 kpa. This TMP pressure initiates the BW of the **RSL membranes™** .
5. The TMP- NTU- Time curve repeats after the BW.

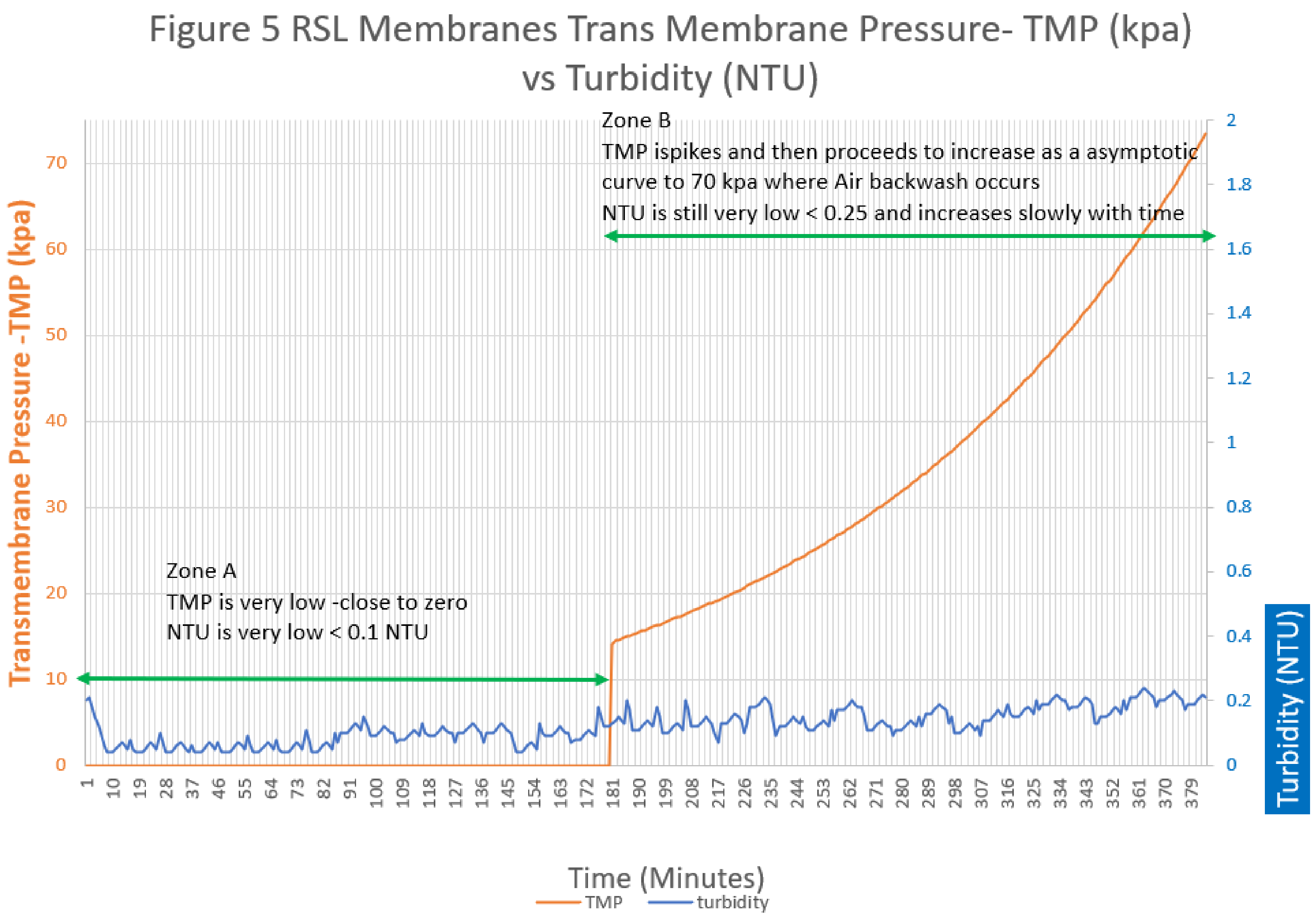

Figure 5 RSL Membranes Trans Membrane Pressure- TMP (kpa) vs Turbidity (NTU)

Conclusions

RSL Membranes™ are a new and distinct membrane treatment method for liquids. The technology does not rely on a physical barrier like conventional low pressure and dynamic membranes. The fact that the RSL membranes™ operate for a significant portion of the filtration cycle with a TMP close to zero kpa can be explained by the manipulation of the electric double layer on the colloids. The DLVO theory teaches the impact of an ionic environment on the strength of the EDL. Because of the intense ionic environment caused by the RSL powder™, the colloids are repulsed from the surface of the membrane. RSL Membranes™ operate in a dead-end mode. The repelled colloids concentrate in the membrane housing. Eventually those colloids leak into the RSL powder™. and the EDL collapses. Van der Waal forces become dominant. The colloids aggregate and attach to the RSL powder™. The pressure then spikes and increases asymptotically.