

## Improved Red Mud Flocculants

Alpha Barry<sup>1</sup>, Christopher Cross<sup>2</sup>, Airong Song<sup>3</sup>, Pablo Mendez<sup>4</sup>, Askia Barry<sup>5</sup> and Ryan Zheng<sup>6</sup>

1. Bayer Process Expert, Solvay
  2. Formulations, Applications and Development Manager, Solvay
  3. Principal Scientist, Solvay
  4. Regional Account Manager, Solvay
  5. Application Technician, Solvay
  6. Global Marketing Manager - Alumina & Industrial Minerals  
Solvay, Stamford, CT, USA
- Corresponding author: alpha.barry@solvay.com

### Abstract

Solvay introduced hydroxamated flocculants (HX) to the Alumina industry in the 90s. This breakthrough technology resulted in a leap in the Bayer Process red mud settling efficiency and in settler throughput. Solvay's HX technology has been evolving over the years. Now, with the new generation CYFLOC® HX-6000 series, Solvay offers a more cost-effective line of products, translating to a significant reduction in required dose and treatment cost for the same or superior vessel performance. Customers also gain sustainability benefits, such as Nonylphenol ethoxylate (NPE) free products, reduced inventory and logistics costs. Solvay's customers who have converted the older series of HX to the new generation of products, are benefiting from improved performance from this new technology. CYFLOC® HX-6000 series, have been trialed and are being used at many refineries since 2018. Reported settler key performance parameters: throughput, overflow clarity, underflow density and dosage indicate an outstanding control of the mud settling process with dosage reductions in the range of 25-30 %. This paper presents the results of laboratory experiments conducted in some of Solvay's customer laboratories.

**Keywords:** Hydroxamated flocculants (HX), CYFLOC® HX-6XXX, Red mud, Settler, NPE free.

### 1. Introduction

#### 1.1 New 6000 Series

For more than a century, the Bayer process has been the main commercial process used for producing alumina from the caustic digestion of bauxite ore. The separation of the red mud from the alumina rich liquor resulting from the digestion process, is a critical step that occurs in the settlers and is aided by the application of synthetic flocculants. The optimization of settler throughput, overflow clarity and underflow density require performant flocculant technologies.

Due to the challenges of the settling characteristics of bauxite slurries, considerable research focused on creating robust and versatile flocculant technologies has been a priority of Solvay innovation teams.

As a result, after the first generation of its breakthrough hydroxamated technology was commercialized in the 90's [1-4], Solvay continued extensive efforts to improve the robustness, cost effectiveness, performance, and sustainability of the product.

The most recent Solvay HX series, CYFLOC® HX-6000, was developed with an emphasis on improvements in the manufacturing process. These improvements resulted in a highly effective

distribution of hydroxamate functional groups on the molecules' backbone, enhancing the flocculants performance with no safety downfalls in comparison with previous Solvay hydroxamated polyacrylamide flocculants.

Since 2018, CYFLOC® HX-6000 series, have been commercially applied in several refineries. Reported settler key performance parameters such throughput, overflow clarity, underflow density and dosage indicate outstanding performances at reduced treatment costs. The HX-6000 series has reduced the dosage by  $\geq 25\%$  when compared to the other series.

The previous HX-PAM generation products include nonylphenol ethoxylate (NPE) in their formulations. Surfonic N-95 is a surfactant containing Nonylphenol and is considered one of Nonylphenol Ethoxylates (NPEs) that are under Environmental protection agency's Significant New Use Rule (SNUR) regulation. The Rule requires the agency's review before a manufacturer starts or resumes the use of NPEs. Therefore, there was a need to develop a new class of HXPAMs without N-95.

## 1.2 NPE free Products

The NPE chemicals are toxic to aquatic life and have some potential negative effects on humans and animals, such as disrupting the body's hormonal system. More and more countries are expected to limit the use of NPE-containing chemicals in industrial products.

To align with the global trend for more sustainable products, Solvay has formulated an NPE-free CYFLOC® HX for each of its active products that provides the same flocculation performance as the corresponding NPE formulations.

Solvay has rolled out the NPE free formulation in Europe and introducing the technology to its customers in countries where the regulation is not yet enforced. In the long term, all customers will be switched to these sustainable products.

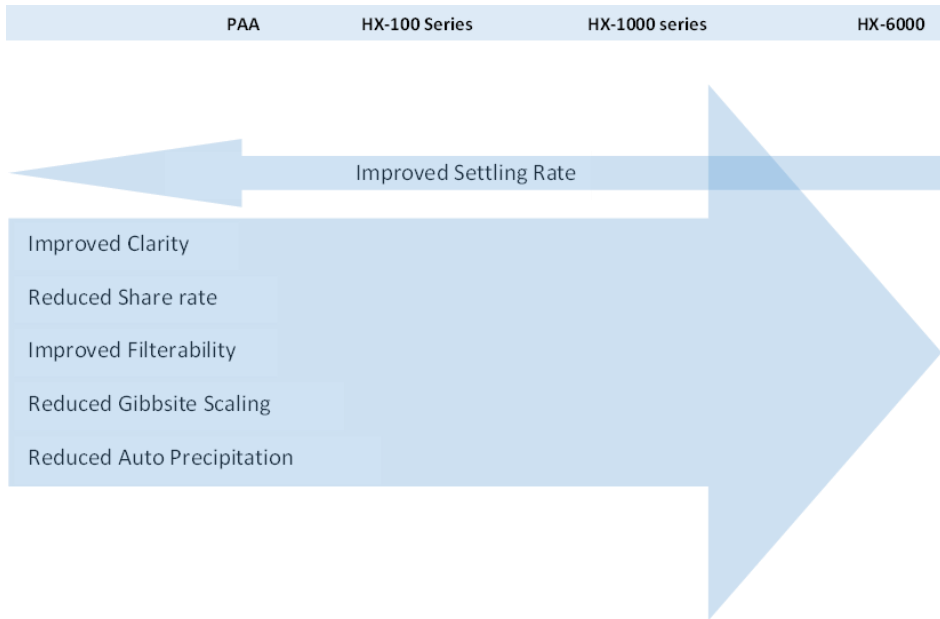
## 2. CYFLOC® HX a Short History

The HX technology was discovered and patented by Solvay in 1985. These flocculants have demonstrated to be very effective with respect to improving overflow clarity, filtration rate, underflow rheology, handling difficult to settle mud, and in general, providing more stable operations in Bayer process solid-liquid separations.

Since that initial introduction, three generations of products have been introduced as shown on the timeline below.

- **1985** : Discovery of HX as red mud flocculants
- **1989**: 1<sup>st</sup> Production of S-6703 Gel
- **1992** : 1<sup>st</sup> Commercial sale of HX emulsion 100 series
- **1998** : Commercial sale of 1000 series,
- **2018** : Commercial sale of 6000 series,
- **2021**: Commercial sale of CYFLOC® HX NPE free products.

Each new generation brought improved settling rate, overflow clarity and underflow density. As illustrated on Figure 1 below, each series includes several variants that can be tailored to specific slurry settling characteristics or to the specific customer needs such as superior overflow clarity, or higher throughput. The injections points and all application guidelines are similar for all products.



**Figure 1. Relative Performance of HX series.**

### 3. Laboratory Procedure

Flocculant laboratory tests are conducted by the traditional cylinder settling test procedure. In the laboratory, flocculant samples are diluted to suitable concentrations (typically 0.1 % in the lab) in plant process water. Deionized (DI) water is only used in the laboratory. In plants all tests are performed in process water. With process water there is no different in performance.

Diluted blow off slurry was collected from the plant, to simulate settler operation, and was held at temperature (90 to 100 °C) in water baths during the execution of the procedure. A few samples of the slurry are filtered to determine the solid content.

The slurry is then poured into several cylinders, held at temperature in a water bath. The cylinders are removed one at the time from the water bath, a known dose of flocculants is added, adequately mixed and the settling test carried out.

For each dose added, the following parameters are measured and recorded:

- Volume of flocculant added (ml).
- The time in seconds the interface drops a known distance.
- Volume of settled mud after 15 minutes (ml)
- The turbidity of the supernatant after 15 minutes (mg/l or NTU)
- Settling rate (meter per hours) is calculated.
- Dosage (grams of flocculant per ton of mud) is then calculated.

The data set generated is then graphed to compare the relative performance of various products at different dosages.

### 4. Results and Discussions

Since the 1980's, Solvay's teams have collected numerous settling test data sets from in its laboratories and in its customer laboratories. The following data set samples were generated at a few customer site laboratories during product selection tests. They show the evolution of the

performance of Solvay CYFLOC® HX product line. There is only one plant (plant1) where lab data was generated on the same slurry using the three HX series. The liquor/bauxite characteristics of every plant varies, as a result the KPI's versus dosage are different; leading to the groups of graphs below.

#### 4.1 Results for HX Series Comparison for Plant 1

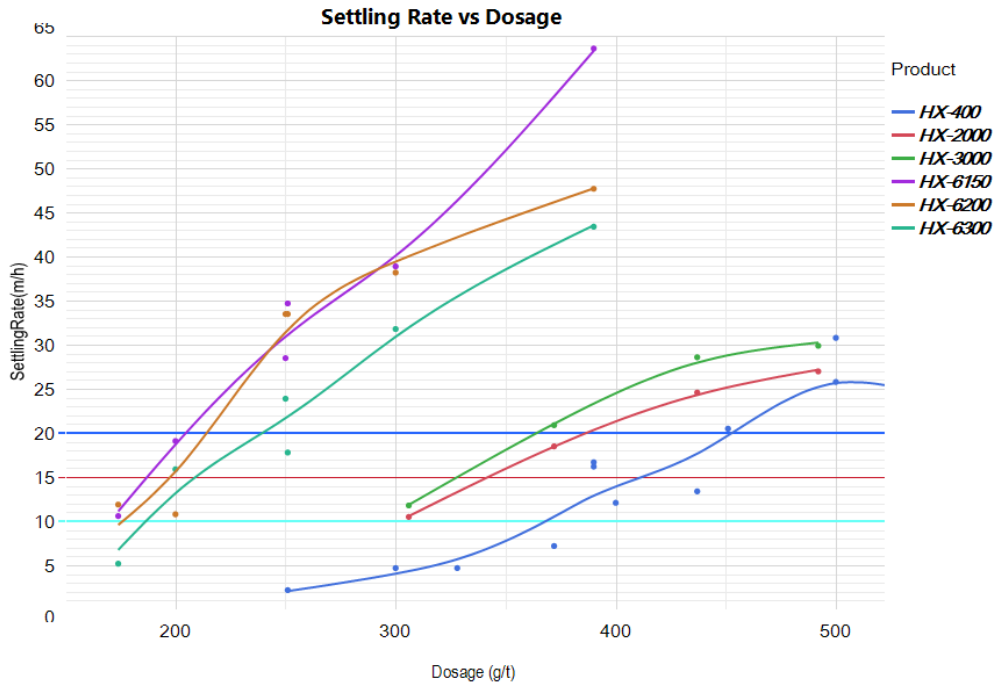


Figure 2. Settling rate vs dosage lab test Plant 1.

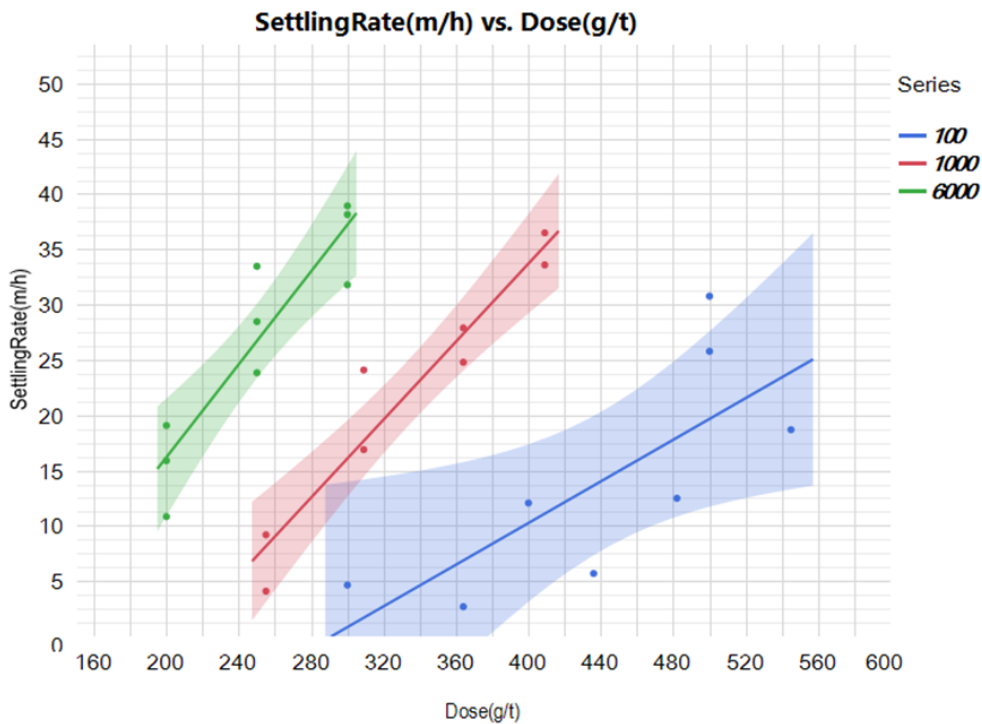


Figure 3. Settling rate (m/h) vs dosage lab tests Plant1.

#### 4.2 Results from HX Series Comparison for Plant 2

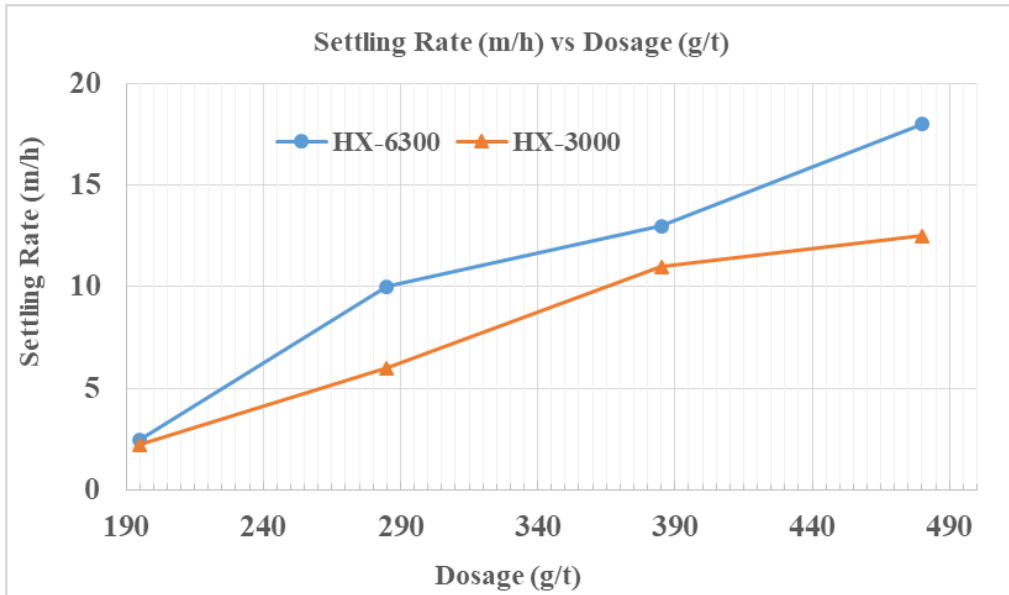


Figure 4. Settling rate vs dosage (g/t) lab test Plant 2.

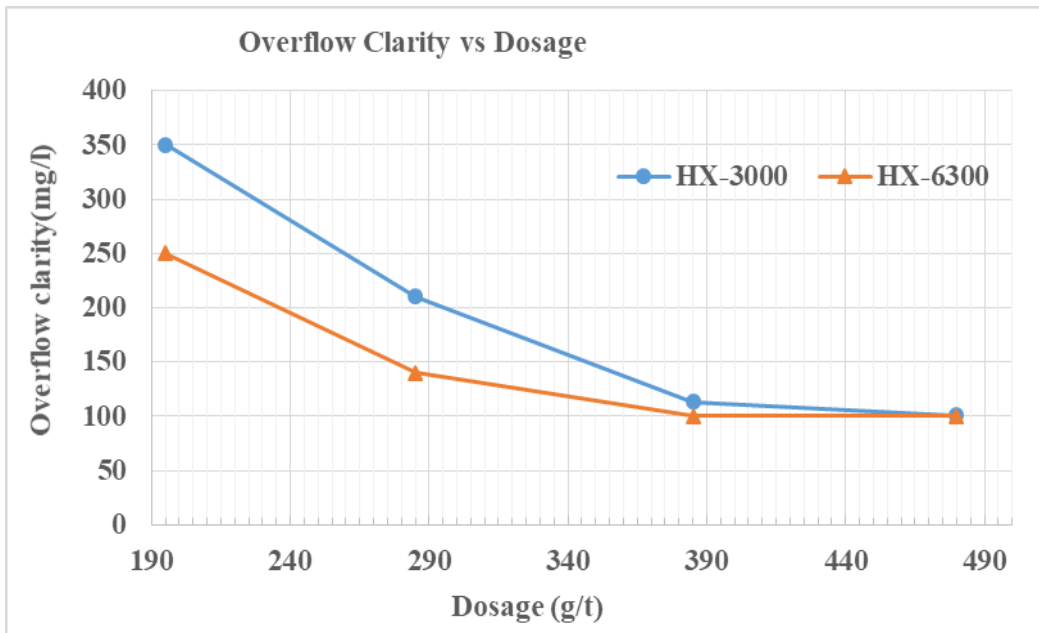


Figure 5. Overflow clarity (m/l) vs dosage (g/t) lab test Plant 2.

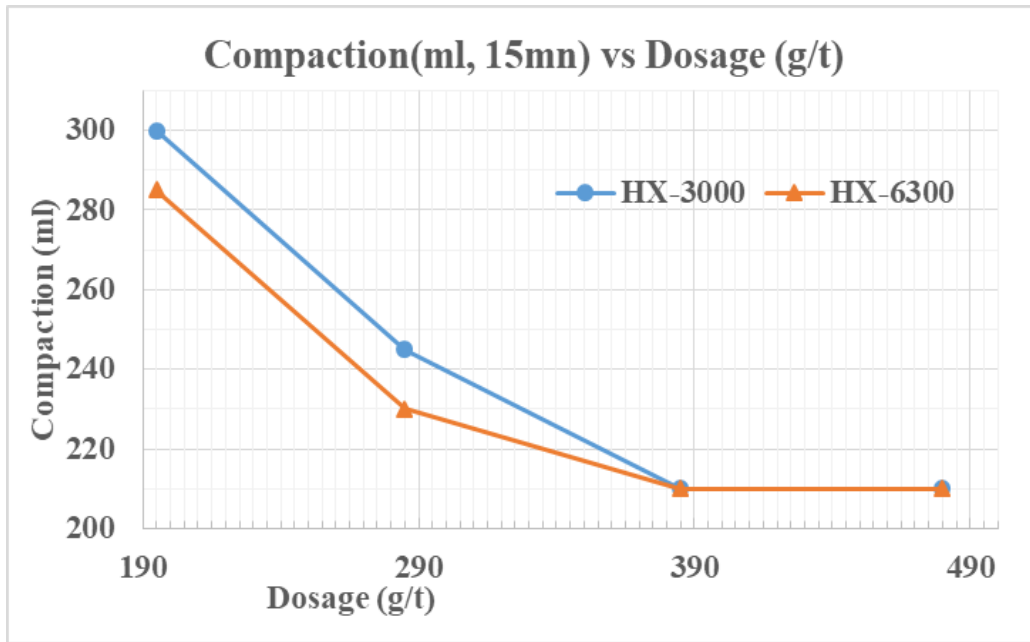


Figure 6. Volume of mud vs dosage after 15 min (ml) Plant 2.

#### 4.3 Results for HX Series Comparison for Plant 3

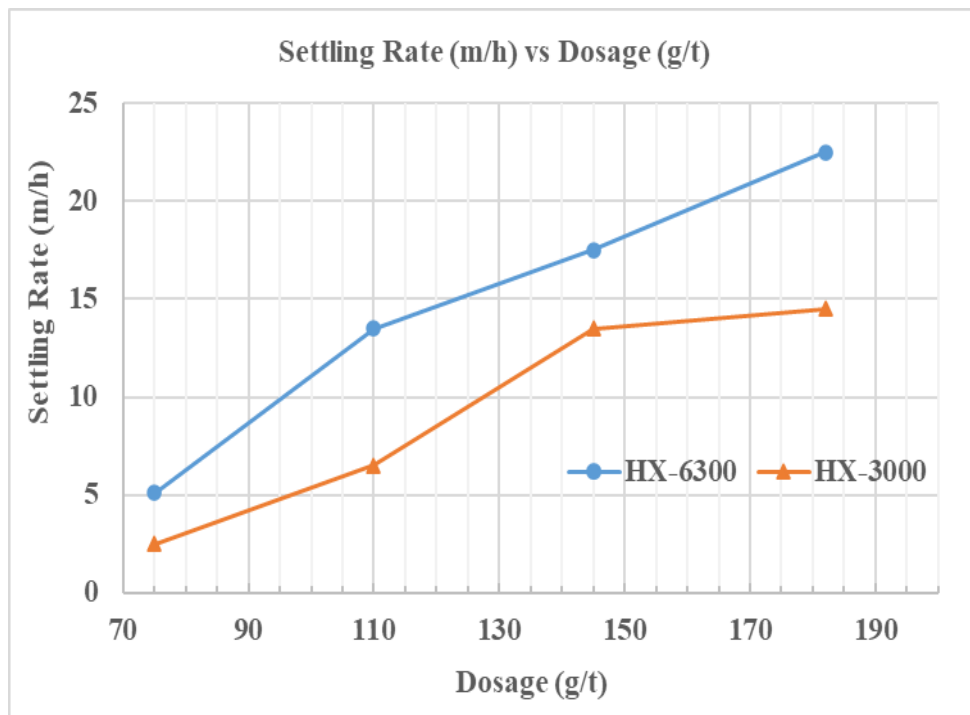


Figure 7. Settling rate (m/h) vs dosage lab tests Plant 3.

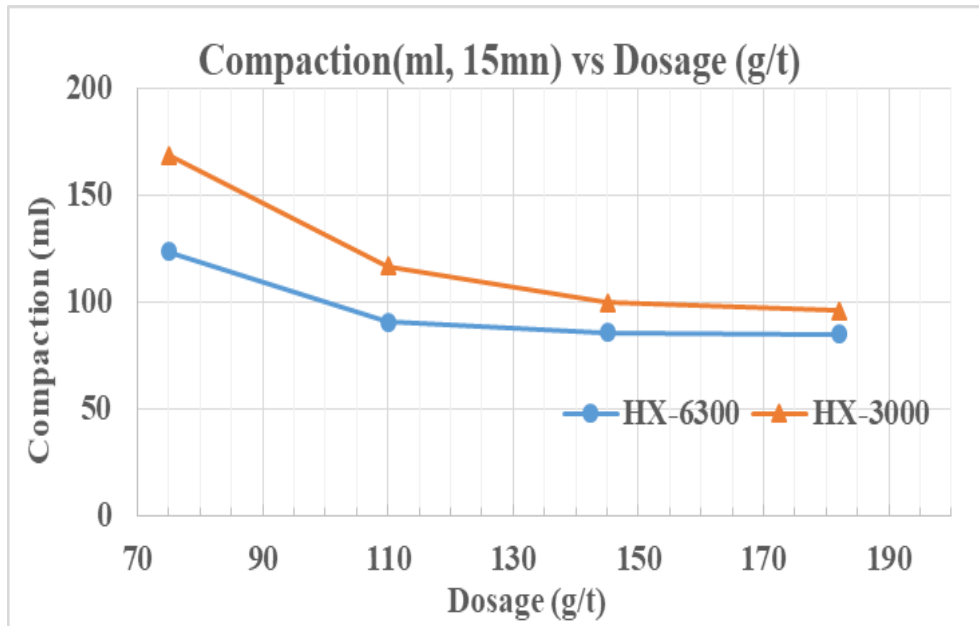


Figure 8. Volume of mud vs dosage after 15 min (ml) Plant 3.

#### 4.4 NPE Free Products

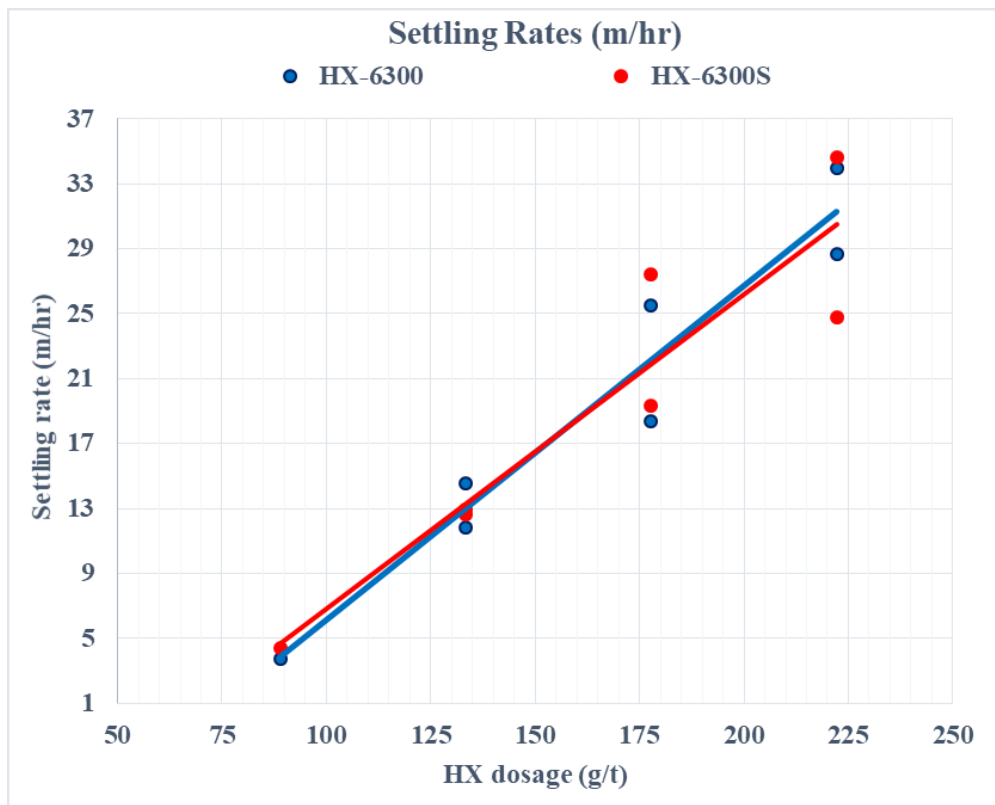
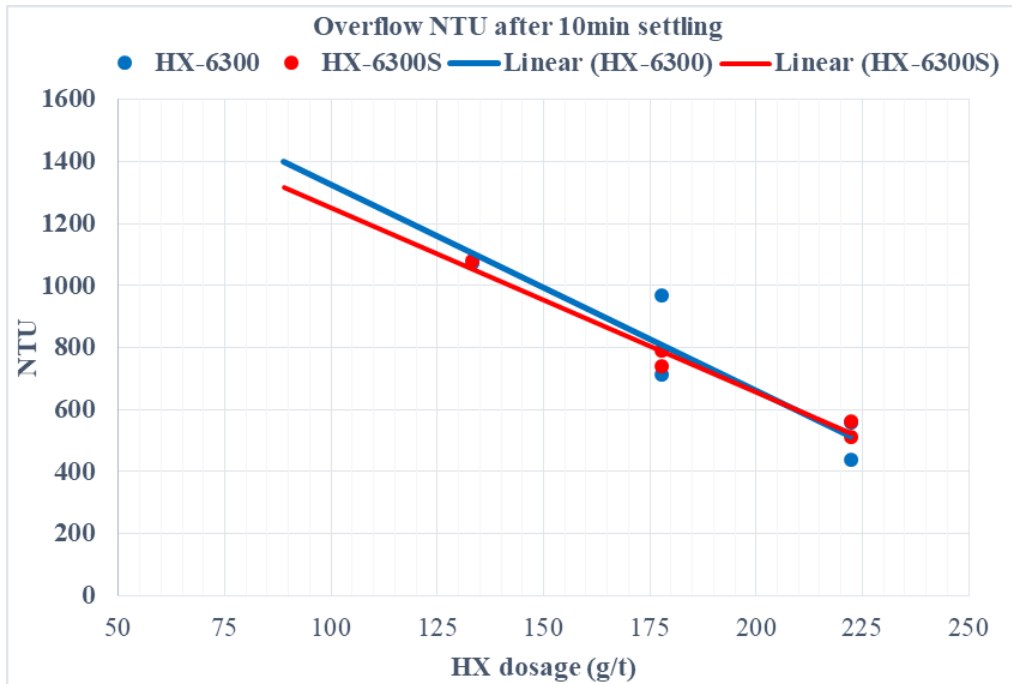
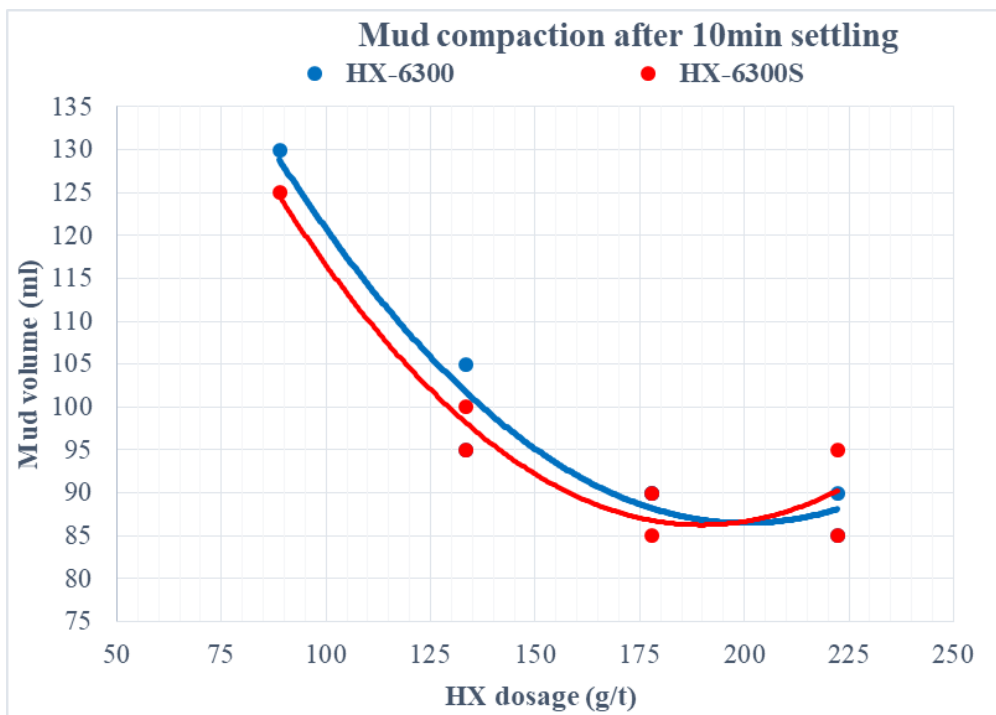


Figure 9. Comparison HX6300S (NPE free) vs HX 6000 (NPE formulation).



**Figure 10. Overflow clarity comparison of HX6300S (NPE free) vs HX 6000 (NPE formulation).**



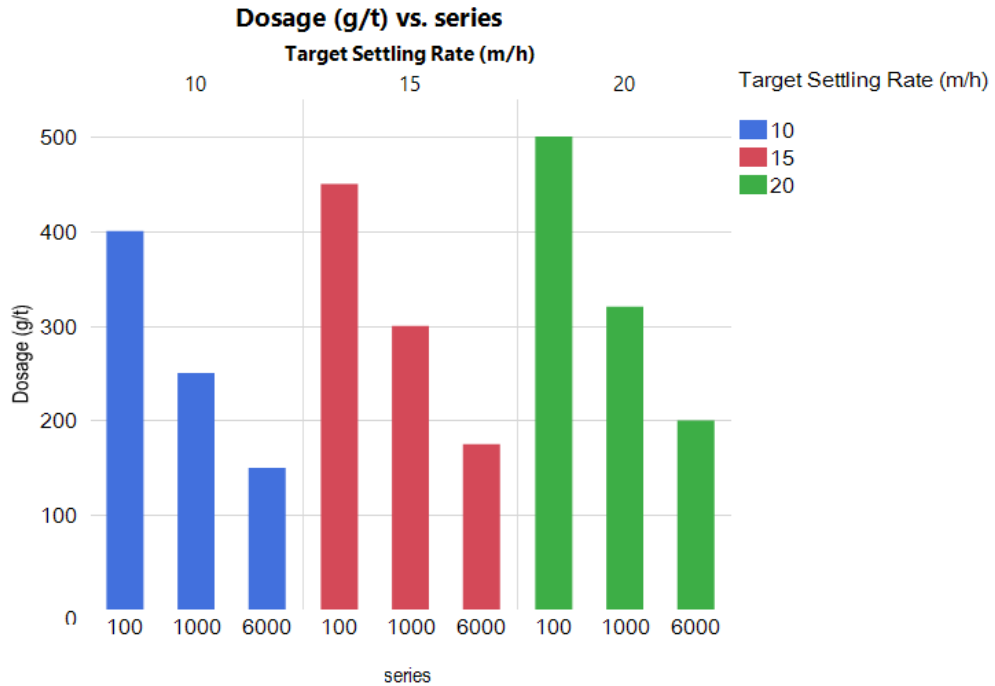
**Figure 11. Compaction comparison for HX6300S (NPE free) vs HX 6000 (NPE formulation).**

## 5. Average Dosage Reduction

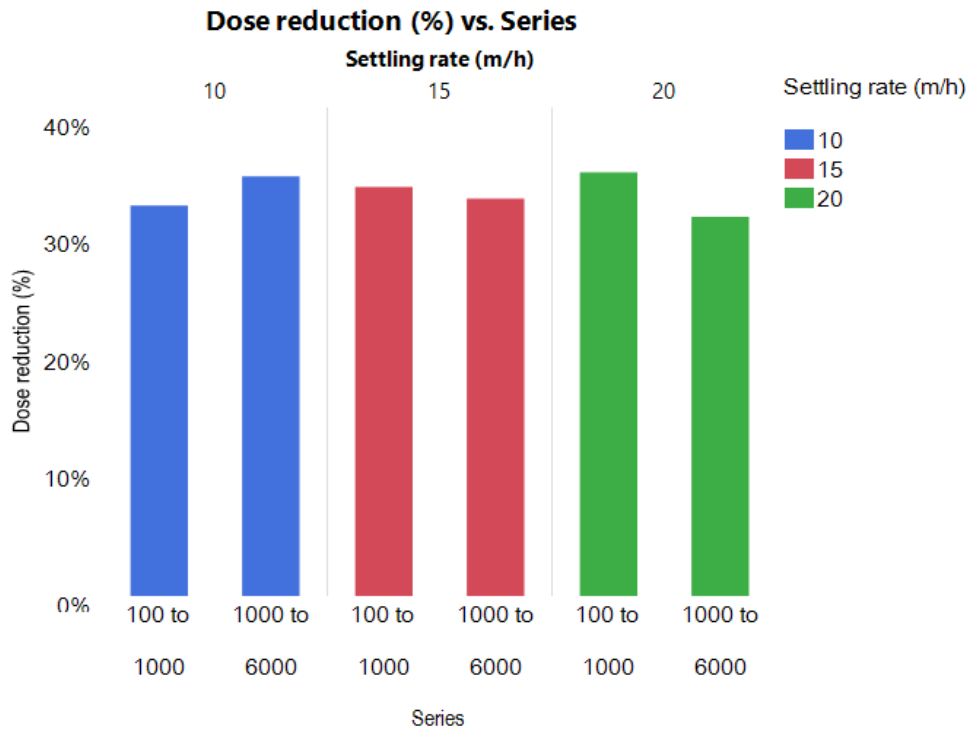
Using the results from plant1, where all the 3 generations were tested on the same slurry, the comparison of the results are shown below (Figures 12–13 and Table 1) for typical settling rates (10, 15, 20 m/h).

**Table 1. Dosage (g/t) vs target settling rate lab tests.**

Target Settling Rate (m/h)	100 series	1000 series	6000 series
10	400	250	150
15	450	300	175
20	500	320	200



**Figure 12. Dose required (g/t of mud) to achieve target settling rates.**



**Figure 13. Dose reduction (%) to achieve a target settling rate.**

## 6. Plant Application

Since their introduction, the new HX generation series have been adopted by most of Solvay's customers worldwide. Dosage reductions observed are in the range of 20 to 25 % in comparison to 1000 series for equivalent or superior performances. The new HX series application guidelines are consistent to those of the old generations, in terms of dilutions, spilt dosage, water quality etc.

## 7. Conclusions

Laboratory results have demonstrated that by applying CYFLOC® HX-6000 series it is possible to achieve a dosage reduction of approximately 25 to 30 % in comparison to CYFLOC® HX-1000 series, and 50 to 60 % in comparison to CYFLOC® HX-100 when evaluating settling rate and clarity as response variables. For these reasons, the CYFLOC® HX-6000 series has been implemented by most of Solvay's customers. CYFLOC® HX-6000 series offer a more robust and cost-effective line of red mud settling flocculants. The main features of these new products include a significant reduction in required dosage relative to current products, improved KPI's and addresses the requirement of the new regulations on sustainability.

## 8. References

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## Abbreviations

PAA: Polyacrylamide  
HX: hydroxamated polyacrylamide  
NPE: Nonylphenol Ethoxylates