ABSTRACT

Particle segregation is a common, but often neglected problem in bulk solids handling. It is induced by mechanical stresses suffered by a bed of material when vibrated, allowed to freely fall or transfer, provoking particles to reaccommodate size-biased. This phenomenon triggers a series of upsets in production lines. In fertilizer granulation plants, some quality issues of final product and overall process control disturbances can be explained by excess of segregated material being fed to process screening machines. This paper is a case study of sieving inefficiency troubleshooting that took place in an NPK granulation plant in India, where the lack of proper transition between product bucket elevator and a conveyor belt caused material to suffer trajectory segregation. As a result, the granulometry distribution profile on belt was increasingly coarser along its width moving away from elevator’s discharge. When that conveyor fed a pair of screening machines through a stream splitter, one was receiving an excess of undersized particles whereas the other an excess of oversized ones. Even though same flow was being achieved on both machines, a more segregated and homogenous mixture fed to them decreased overall screening efficiency. Poor sieving results in excess of feed to oversize grinders and reduced recycle back to granulator, destabilizing recycle control system and overall granulation process. Given the impossibility of revamping or replacing the existing transition, in this case an inclined chute, palliative measures showed necessary and enough to reduce segregation, increasing screening efficiency to as high as 96% and stabilizing recycle control.
Key words: Mechanisms of Segregation, Recycle Control, NPK granulation.

RESUMO

A segregação de partículas é um problema comum, mas muitas vezes negligenciado, no manuseio de sólidos a granel. É induzido por tensões mecânicas sofridas por um leito de material quando vibrado, permitido cair ou transferir livremente, provocando partículas que reacomodam a polarização de tamanho. Esse fenômeno desencadeia uma série de transtornos nas linhas de produção. Nas plantas de granulação de fertilizantes, alguns problemas de qualidade do produto final e distúrbios gerais no controle do processo podem ser explicados pelo excesso de material segregado sendo alimentado nas máquinas de triagem de processo. Este artigo é um estudo de caso de solução de problemas de ineficiência de peneiramento que ocorreu em uma planta de granulação NPK na Índia, onde a falta de transição adequada entre o elevador de caçamba do produto e uma correia transportadora fez com que o material sofresse segregação de trajetória. Como resultado, o perfil de distribuição de granulometria na correia ficou cada vez mais grosso ao longo de sua largura, afastando-se da descarga do elevador. Quando esse transportador alimentava um par de máquinas de peneirar através de um divisor de fluxo, um estava recebendo um excesso de partículas de tamanho menor, enquanto o outro um excesso de partículas de tamanho grande. Embora o mesmo fluxo estivesse sendo alcançado nas duas máquinas, uma mistura mais segregada e homogênea fornecida a elas diminuiu a eficiência geral da triagem. Uma peneira ruim resulta em excesso de alimentação para trituradores de tamanho grande e reduz a reciclagem de volta ao granulador, desestabilizando o sistema de controle de reciclagem e o processo geral de granulação. Dada a impossibilidade de renovar ou substituir a transição existente, neste caso, uma rampa inclinada, as medidas paliativas mostraram-se necessárias e suficientes para reduzir a segregação, aumentando a eficiência da triagem para até 96% e estabilizando o controle da reciclagem.

Palavras Chaves: Mecanismos de Segregação, Controle de Reciclagem, granulação NPK.

1 INTRODUCTION

The present paper is a case study of a granulation process control troubleshooting that took place in a granulation unit in India (referred to as factory onward) during the last week of May of 2018. Factory had revamped one of its multi-purpose granulation train acquiring two 5’x20’ double deck inclined high frequency screening machines with modulating control valve for recycle control and a 2-way stream splitter. After startup of the plant with new recycle control system through the modulating control valve underneath the screening machines’ fines hoppers, factory started experiencing process instability caused by lack of recycle material back to granulator, increased presence of oversize and reduced overall physical quality in final product. Supplier was requested to investigate in loco possible causes of issues and to address them to restore plants normal capability of producing good quality >2 mm to <4 mm material. Usually, granulation process problems derive from chemical input
imbalances but, when that does not seem to be case, one must look at the behavior of bulk solids during handling in the production line to identify points where flow issues may be arising unnoticed such as particle segregation.

2 TYPICAL NPK GRANULATION UNIT

Typical NPK granulation plants deal with both solid and liquid raw materials feed such as anhydrous ammonia and phosphate acid, Potash, Triple Super Phosphates, Urea, etc. DAP and MAP plants’ flowchart will contain a pipe reactor [1] or a pre-neutralizer. The granulation will occur inside the granulator that feeds a dryer, which will discharge its content into a lump breaker to reduce lumps over 25 mm in diameter, so that a bucket elevator can elevate conditioned material to a stream splitter used to equally divide the flow to as many oversize screening machines as are installed in the line. There must be a well-designed chute work and/or conveyor belt system. The screening system begins with the screen feeders. These machines are used to allow for material to be uniformly fed across full width of wire cloths inside screeners for optimum screening performance.

Oversize screening is composed of two-surface screening machines that separate fed material in three different streams: oversize, fines (undersize) and good product. The preferred type for 2x4 mm separation in NPK granulation plants is inclined vibratory machines with oversize slotted wire cloths with mesh openings around 4.2 mm. The undersize wire cloth openings can vary from 2.2 mm to 3 mm. Oversize product is sent to oversize grinders for size reduction. There are multiple types of crushers such as roller mills, drum mills, cage mills and chain mills [2]. These machines should reduce all oversized material to <4 mm. Undersize passing through the second deck’s wire cloth of screeners are sent to recycle conveying system and then back to granulator. Good 2x4 mm product is sent to product single-surface (polishing) screening machines for scalping then to rotary drum coolers and further storage. Material passing through it is sent directly to recycle conveyor while material going over it is sent to storage. All recycle material from screening machines, cyclones and crushers is discharged to the recycle conveyors then back to the granulator through the granulator feed elevator.

The ability of granulation plants to produce good product with great physical quality properties will highly depend upon many factors. There must be precise control of all unit operations involved in the production steps and a good flow of bulk solids throughout the entire plant, but controlling the recycle loop seems to be the most effective way to stabilize process and to achieve a narrower granulometry on its upper range (>3 mm to <4 mm). This
is where the modulating control valve underneath the oversize screening machines’ fines hopper comes in. But what exactly is it and, most importantly, how does it work?

3 RECYCLE CONTROL VIA MODULATING CONTROL VALVE WITHIN SCREENING SYSTEM

A typical configuration for vibrating double-deck screens for most fertilizer applications is for the upper deck wire cloth’s openings to be sized to 4.2 mm and the lower deck ones sized to 2.4 mm [3]. Figure 1 illustrates the action of separation.

All of the material below 2 mm in the fines hopper is discharged directly onto the recycle belt. The production of good product-size material is determined not only by the raw materials going into the granulator but also by controlling the amount of recycle material returned to it, made up of undersize from the screening machine’s hopper combined with oversize material pulverized by grinders. There is usually no control of the amount of recycle material after screening process and, consequently, there is only partial control of the granulation process [3].

More advanced recycle control is available with the use of a modulating control valve underneath a modified fines hopper of oversize screens and a proper lower deck wire cloth sizing can be selected to optimize granulation production and quality. Instead of every panel on this deck having a 2.4 mm opening, meshes are gradually increased from feed end to discharge end as Figure 2 illustrates. This was first done by J&H Equipment, Inc. in granulation projects in Australia.
The reason for this is to create a gradation of material size falling through the lower deck progressing from feed end to discharge end, which will be enhanced by the vibration of the wire cloths. Nothing changes in the upper deck, where >4 mm material will still be sent to oversize grinders.

Regarding material within good product size range, <4 mm material that reaches the lower deck wire cloths will be progressively separated by larger and larger meshes. By the end of screening process, product material remaining on the wire cloth will be mostly 2.8 mm to 4.0 mm sized material. This high-quality product material still goes out to product chute.

This configuration is made to allow for the use of the modulating control valve in the fines hopper (seen in Figure 2 – left side). Taking a closer look at the insides of the hopper (detail in Figure 2 on the right side), one can see a separator blade starting right at the junction of the second with the third wire cloth and perceive that 2.3 mm and 2.5 mm will still separate undersize and send them to recycle. The difference is that the two consecutive panels will have the material passing through them diverted by the separator plate (seen in yellow in Figure 3 right side). This is made so the modulating control valve can select the size of material that should be sent back as recycle, or onward as good product. This is the key to increasing recycle control.

Above the valve portion of the hopper, the separator plate is beveled to create an extended cut of material falling into the control valve, whose blade can select material regarding size of particles through the falling stream. If the blade is set to the “closed” (0%) position (towards the interior of the hopper), the entirety of that stream will be diverted to product chute, whereas if the blade is set to the “open” (100%) position (towards the opposite end) the entirety of the stream will be diverted to recycle. The control resides in that the blade can be positioned in whatever position between “closed” and “open”. The more the blade
moves towards the “open” position, the greater in size the material selected to return as recycle will be. Figure 3 shows the falling stream with increasing particle size. Oversize granules are shown in purple, undersize in blue shades and product range particles in green shades (the coarser the particle the darker the shade).

![Figure 3](image.png)

Figure 3 – Illustration of the modulating control valve selecting particles in size [3].

The material directed into the modulating control valve over and sliding down the beveled edged of the separator plate is from 2.2 mm to 2.8 mm. Choosing the size of product going back as recycle can help in reducing the amount of dry material going back to granulator if the material is already too dry and liquid feed input is not easily adjustable, gradually bring down plant operating capacity without dumping material, quickly increase quantity of dry product back to granulator to help stabilize the process’ chemical reaction (especially right after start up), increase or decrease output diameter size of granules coming out granulator, among other features. Such system reveals to be an important fine-tuning tool in process control, allowing for operators to quickly intervene in the recycle loop to achieve immediate results. This system, however, is not immune to process upsets, but on the contrary. It is still necessary to maintain good solids handling throughout the production line to ensure efficient screening system, especially because some of the problems encountered in granulation plants are related to bulk solids flow, more specifically, particle segregation.

4 MECHANISMS OF SEGREGATION

According to IFDC’s Fertilizer manual, the acceptability of a fertilizer in the marketplace depends not only on its nutrient content but also on its physical quality [4].
Performance of many fertilizers is affected by the homogeneity of particle sizes or blend component population throughout the bulk [5]. The classical problem associated with the loss in homogeneity of particle sizes in bulk is segregation, which is the ability of particles within a bulk blend or bed of material to separate according to size. Many other physical properties of particles can yield segregation, but difference in size has been shown to play a greater role [6]. The basic explanation behind this phenomenon is that the interconnection of particles bigger in diameter will create voids that will allow for smaller particles to percolate through them [7].

Segregation can take place at multiple stages of the manufacturing, during transportation or even in the field distribution stages for fertilizer materials [5]. There are many types of mechanical disturbances that will cause particles to segregate. All of them are either one or a combination of four mechanisms of segregation according to size. They are: trajectory segregation, percolation of small particles, Brazil Nut Effect and elutriation [8]. Figure 4 illustrates three types of segregation.

![Figure 4 – Some Mechanisms of segregation [7].](image)

### 5 TRAJECTORY SEGREGATION

Taggart (1927) [9] pointed out that coarser particles that move along an inclined surface will be discharged further away from the end of that surface than those of smaller diameters. Experiments on trajectory segregation have been present in the literature for many years. One of them aimed to observe the behavior of particles during a heap formation from an inclined silo output. After complete conical heap formation, it was divided in six sections as shown in Figure 5, evidencing that a predominance of smaller particles closer to the discharge end of that feeding silo [10] (right half of heap had 2.77 times more undersize...
particles than the left one). Bicking (1967) [11] conducted a similar study and obtained equal results.

![Diagram of a silo and chute with percentage distributions](image)

Figure 5 – Percentage of small particles shown in each of 6 sections of a heap [10].

Mitchell (1938) [12], on the other hand, when studying particle behavior during conveyor belt and feeder feeding, also perceived a discrepancy in the accumulation of smaller particles in regions closer to the feeding point. If a particle of small diameter \( x \) and density \( \rho_p \), whose drag force is governed by Stokes Law, is projected horizontally with initial velocity \( U \) in a fluid of viscosity \( \mu \) and density \( \rho_f \), the limiting distance \( (d) \) that it will travel is given by Equation (1) [7].

\[
d = \frac{U\rho_px^2}{18\mu}
\]  

(1)

Trajectory segregation is commonly composed of other effects such as percolation or friction [13]. Problems in solids handling encountered in a process plant derive from lack of previous knowledge that should have been considered during the drawing board phase, at relatively cheap cost if implemented at this stage [5]. Even though this represents the best-case scenario, segregation may reveal itself a tricky behavior and still show up at later stages and may cause upsets that can arise in the form of erratic flow inside silos (funnel flow vs. mass flow) [14], problems in the feeding rates of feeders, segregation during heap formation [15], overflow of bins, dust generation, segregation during chute transfers, agglomeration by compaction, clogging, among other issues.
6 PROBLEMS IN THE RECYCLE CONTROL SYSTEM OF A FERTILIZER PLANT IN INDIA

Factory had installed two 5’x20’ double deck screening machines with modulating control valve in fines hopper for recycle control, during a revamp project of a multi-purpose granulation plant (Train B) in Gujarat State, India, producing 50 to 60 t/h NPK Grade II (12:32:16), Grade I (10:26:26) or DAP (18:46:00). After plant commissioning and start up, operators began facing issues regarding the operation of the modulating control valve of process screening machine.

For plant start up, the modulating control valve was set to 100% open position, i.e., to send all material passing through the 2.5 mm and 3 mm mesh back as recycle to quickly increase dry product quantity inside granulator to help stabilize process. Figure 6 shows a sketch of the factory’s plant layout.

With time, the granulator started producing bigger particles that would, eventually, be sent to grinders. To avoid this, operators then started moving modulating control valve’s blade towards “closed” position to reduce size profile back to granulator and reach stable condition of operation but, despite this expectation, upon minimal displacement of the blade, operators started facing significant reduction in the recycle rate making process unstable. To quickly correct it, they were forced to move blade back to almost 100% closed position. In normal conditions, this should not be happening. To measure the screening machine’s efficiency in the present situation, one can resort to a simplified method as to quickly identify it and use as a gauge, where the value is the mass fraction of on-size (good product size which will be considered to be >2 mm, <4 mm) material of a sample of the product stream. Screen Efficiency (SE) is, then, given by Equation (2)

\[
SE = \left( \frac{\text{Product Size in Product Stream}}{\text{Total Product Stream}} \right) \times 100 \quad (2)
\]
FIELD OBSERVATIONS AND PROBLEMS ENCOUNTERED

Technical visit took place during the last week of May of 2018 at the factory’s plant, specifically at the Train B whose operating screens are Screen C and Screen D. Sieve analysis before interventions are shown in Table 1, representing the average of 5 samples taken from different points. Mesh openings: Oversize Mesh = 4.2 mm; Undersize Meshes = 2.3 mm, 2.5 mm, 2.8 mm & 3.0 mm.

Table 1 - Sieve Analysis of B Train dated 05/09/2018 (% mass fraction) – before site visit.

| Sample ID                  | + 4 mm | + 3 mm | + 2 mm | + 1 mm | - 1 mm |
|----------------------------|--------|--------|--------|--------|--------|
| Granulator Inlet           | 2.8    | 3.6    | 15.2   | 31.0   | 47.0   |
| Granulator Outlet          | 82.4   | 4.2    | 3.6    | 5.4    | 4.4    |
| Screen Belt Conveyor Inlet | 13.0   | 10.0   | 19.0   | 29.0   | 28     |
| Oversize Screen C          | 90.2   | 6.4    | 2.4    | 1.0    | 0.0    |
| Oversize Screen D          | 91.2   | 6.6    | 1.2    | 1.0    | 0.0    |
| Polishing Screen Outlet    | 1.4    | 27.0   | 44.2   | 25.6   | 1.4    |

It was possible to conclude that the granulator was producing too much oversize (orange highlight in Table 1). As consequence, the oversize crushers (chain mills) started
experiencing a higher feed rate from screens, impacting in the crushing efficiency thus increasing granulometry profile back to granulator from oversize discharge. The scalping screening system was producing 71.2% of the product between good product range (>2 mm to <4 mm – green highlight in Table 1), and that 25.6% of the mass fraction in the lower range of the granulometry (>1 mm to <2 mm) evidencing either that the recycle control was not playing any role in the granulation and that the screening system was working as a standard system, or particles were being broken in between two-surface screens and polishing screen. To cover all aspects of the production process, all the granulation parameters such as molar ratio in the pre-neutralizer, pH in different parts of the plant and moisture levels were investigated and showed to be under control and in normal ranges. The chain mills were checked for possible inefficiency, but no strong evidence could be identified that could impact on the process and still, the operators were not able to operate modulating control valve’s blade to reduce recycle particle size. It was necessary to have a more detailed sieve analysis using test sieves with opening of 4.00 mm, 2.86 mm, 2.50 mm, 2.00 mm, 1.18 mm, 1.00 mm, 0.50 mm. Samples were taken from both screening machines’ feed and product discharge ends for a better picture view of the situation. Results of sieve analysis of samples are shown in Table 2.

Table 2 - Sieve Analysis of B Train dated 05/28/2018 (% mass fraction).

| Location of Sample          | Mesh opening in mm | SE  |
|-----------------------------|--------------------|-----|
|                             | 4      | 3.3 | 6  | 2.8 | 2    | 1.3 | 6  | 1    | 0.5 | Bottom |     |
| Screen C Product Output     | 1      | 3   | 26 | 15  | 43   | 7   | 5  | 0    | 44% |         |
| Screen D Product Output     | 4      | 13  | 75 | 8   | 0    | 0   | 0  | 0    | 96% |         |
| Screen C Feed (Inlet)       | 15     | 3   | 16 | 8   | 27   | 10  | 15 | 6    | 0   | -       |
| Screen D Feed (Inlet)       | 46     | 5   | 15 | 9   | 17   | 3   | 4  | 1    | 0   | -       |

It was possible to verify an unbalanced distribution of oversize feeding Screen C and Screen D (red highlight). Screen C was receiving three times as much oversize as Screen D was. Opposingly, Screen C was receiving more undersized material. As consequence, both screens’ discharge content differed in size profile (yellow and green highlight in Table 2 shows undersize distribution).

By visually inspecting screening machines it was possible to notice that there was not same amount of material running down the first deck on both machines. Feed rate on both screens were equal in t/h, raising the suspicion that the number of particles inside each screen
was not the same. At factory’s B train, there is a bucket elevator feeding a conveyor belt that runs orthogonally to the elevator. That belt feeds a crossed-leg two-way splitter that distributes the material stream to both screening machines. Given the arrangement, it is also possible to visually inspect the material laying on the belt to check for evidences. Figure 7 shows a picture taken of the distribution of material on belt.

Figure 7 – Material distribution on the conveyor belt feeding crossed-leg two-way splitter in the Train B.

Inspecting the material distribution on the conveyor, it is easy to see a segregated mixture of particles where the granulometry profiles gets coarser and coarser to the left side (Figure 7). If that belt shown is divided in two halves, the right one (Screen C feed) had 2.32 times more undersize material (<2 mm) than the left one (Screen D feed). A phenomenon known as trajectory segregation was perceived. As said before, the elevator’s discharge is orthogonally positioned with respect to the belt, so, during discharge, the coarser material was being thrown and deposited on the further edge of belt from elevator’s chute discharge. Problem was made worse when it got to the screening machines via the crossed-leg two-way splitter, whose blade moves from side to side dividing the segregated material in two portions, one composed mostly by coarser particles, and the other by finer ones. Figures 8 exemplifies the situation. With a greater number of finer/smaller particles, Screen C was having trouble separating material since the voids created by small particles make percolation difficult.
Figure 8 – Trajectory segregation at the discharge of bucket elevator to the conveyor belt (left) and result in the stream splitter (right).

Percolation really is a sieving mechanism and, of course, a screening machine is nothing more than a segregating equipment (Brazil Nut effect and percolation type segregation will occur and are desired). Figure 9 illustrates desired behavior of particles inside screening machines.

Figure 9 – Percolation of particles during sieving action aided by Brazil Nut Effect [3].

The physical property that yields segregation the most is difference in particle size within a bulk. Given that the material fed to screens was already highly segregated, the particle size difference inside the screening machines was not as great as it would be if a more heterogeneous mixture was fed to them. This will also make percolation and sieving action inside machines more difficult, yielding some carry-over, i.e., material that should have passed through the meshes that is carried over to discharge, as a result of screening inefficiency, like shown in Table 2 (green and yellow highlight). Screen D is not showing excess undersize in product outlet, but screen C is. Both machines can be set to receive same t/h of material via
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splitter but, obviously, the one receiving more undersize will deal with higher number of particles, thus making sieving even more difficult.

A significant number of particles of diameter <2.8 mm is shown in the product stream of Screen C (70% mass fraction – Table 2 in yellow highlight). Statistically, they could have been sieved by lower deck thus giving option for operators to divert it to recycle via modulating control valve. Knowing the flow rate coming out of product discharge of screens (25 t/h per machine), it is possible to estimate the maximum amount of recycle carried-over and lost in the product stream from Screen C that could have been used as recycle, which could be up to 17.5 t/h (25 t/h of product x mass fraction of <2.8 mm). Screen D had 8% of <2.8 mm, totalizing 2 t/h of maximum possible recycle lost. Of course, this is an estimation, but the figures give an idea of the room left for improvement. If screen’s efficiency is raised and some of this <2.8 mm material can fall through the meshes of last sections of wire cloths, operators would have up to 19.5 t/h of extra undersize material in the form of recycle.

This would leave room for the correct operation of the modulating control valve without destabilizing process. After identifying the problem and its cause, actions were taken in the direction of correcting the flow of particles and reducing segregation on the conveyor belt feeding screening machines so that a more heterogenous mixture was fed to each machine, yielding higher screening efficiency, allowing for a better recycle control via modulating control valve. But how to correct trajectory segregation at the discharge of bucket elevator in an existing plant without replacing the whole transition?

8 CORRECTING SEGREGATION IN THE SCREEN FEED SYSTEM

Transitions between equipment can be tricky at times. It is not always possible to predict how bulk solids will behave precisely after start-up. Therefore, in-depth knowledge of bulk solids handling is desirable during the design phase of equipment and plant layouts. Altering equipment in an existing plant is no easy task and so resorting to inserts, modifications or temporary/palliative provisions may be the only alternative.

At Train B, the transition between elevator and conveyor belt is made by an inclined chute yielding excessive velocity to particles sliding down it. Preferably, when bulk solids are transitioned orthogonally between equipment, a specific type of chute (often called spoon chutes) should be designed to reduce particles velocity and avoid segregation during transfer. Given the impossibility of replacing the existing chute, it was necessary to adapt it to redirect material discharged by the elevator to the centerline of the belt, reducing trajectory
segregation. A stripped conveyor belt rubber curtain was fabricated and inserted at the inclined portion of the chute, like the sketch in Figure 11.

![Figure 11 – Sketch of the rubber curtain installation.](image)

9 RESULTS OF INTERVENTIONS

Sieve analysis made after the intervention showed that trajectory segregation really was causing the decreased screening efficiency. Table 3 shows the results of samples taken right after start-up.

Analyzing the data obtained, it is possible to see an even distribution of particle sizes in the feed to both screening machines, so the product output showed no undersize in the product stream output. Data also showed a slightly high amount of oversize (>4 mm) present in the good product stream. If the wire cloth is not damaged, this is physically impossible, given that the mesh openings are set to 4.2 mm. In fact, after visual inspection, some of the upper deck wire cloths of the screening machines were damaged, causing some leakage of oversized particles to good product stream. By operating with segregated material, Screen D was dealing with bigger lumps that can cause damages to wire cloth due to higher occurrence of impacts. Screen C, on the other hand, was dealing with an excess of particles in number, overloading the first deck with carry-over thus suffering more friction stress on wires. Since there was carry-over happening before intervention, this problem was not detected in the sieve analysis. Cloths replacement was necessary. Screen C experienced an increase in its efficiency from 44% to 87.9% after correction of segregation, while Screen D showed a little decrease in efficiency from 96% to 87.4%. By being able to recover the recycle material once lost and operate the recycle control, it was possible to bring final product granulometry to its upper end (<4 mm, >2.8 mm) from 58.5% to 76.6% (average of both screens). Lastly, a sieve analysis after oversize wire cloths replacement (06/01/2018) showed 93% of on-size product in Screen C and 96% in Screen D.
Table 3 – Sieve analysis taken after intervention. Product output results show average of 5 samples taken with 30 minutes interval and Screen Feed results show average of 2 samples taken with 30 minutes interval.

| Location of Sample | Mesh opening in mm | SE  |
|--------------------|--------------------|-----|
|                    | 4.00 | 3.3 | 2.8 | 2.0 | 1.3 | 1.0 | 0.5 | Bottom |
| Screen C Product Out | 11.4 | 14.4 | 62.6 | 10.9 | 0.7 | 0.0 | 0.0 | 0.0 | 87.9% |
| Screen D Product Out | 12.4 | 13.0 | 63.1 | 11.3 | 0.2 | 0.0 | 0.0 | 0.0 | 87.4% |
| Screen C Feed | 14 | 3.5 | 12.5 | 24.5 | 18.5 | 10.0 | 12.5 | 4.5 | - |
| Screen D Feed | 19 | 3.0 | 13.0 | 22.5 | 16.5 | 9.0 | 12.0 | 5.0 | - |

10 CONCLUSIONS

This study confirms that segregation is a serious material handling problem that greatly impacts NPK process plant operation, screening and product physical quality. The correct phase for preventing segregation is the design phase of plant layout and equipment, although, existing plants can suffer palliative adaptations and revamps to correct and/or mitigate issue. When finer treatment needs to be done in fertilizer particles such as in the recycle control system, segregation can reveal itself in steps where it was not noticeable before, resulting in recycle loss and in an instability of process.

Even though screening machines are segregating equipment, more homogenous mixture of particles fed to them will cause machines to work below expected efficiency, whereas a more heterogenous mixture is desired to allow for particles to percolate easier with vibration, making smaller particles descend inside the bed of material and pass through meshes more rapidly.

By addressing segregation in the feed and restoring screening machines’ normal conditions, screening system’s performance increases substantially, bringing SE to as high as 96%. The active recycle control system is dependable on efficient screening system and shows to be utterly reliable and effective in increasing final product physical quality and overall process efficiency.
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