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IRON ORE WASHING – ACHIEVE MORE WITH FEWER RESOURCES

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ABSTRACT. Producers of primary resources such as iron ore face the challenge of processing crude materials with increasing levels of impurities, which may result in the requirement for wet processing. This requirement results in a significant increase in water usage, power consumption and operating costs. Given the remote locations of most operations in Australia [2, 6], the required volumes of power and fresh water for wet processing can be very difficult to achieve. HAVER&TYLER is renowned across the world for their screening technology in wet and dry processes. The innovative Hydro-Clean® system represents a technology that may offer a cost-effective and eco-sensitive way to clean any crude materials and material blends with a grain size distribution of 0–150 mm that are contaminated with adhesive clay, slit and other impurities.

ОБОГАТЯВАНЕ НА ЖЕЛЯЗНА РУДА – КАК ДА ГО ПОСТИГНЕМ С ПО-МАЛКО РЕСУРСИ

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РЕЗЮМЕ. Производителите на основните ресурси, като желязна руда, са изправени пред предизвикателството да преработват необогатената руда с все повече примеси, което може да доведе до необходимост от водни процеси при обогатяването. Това изискване води до повишена консумация на вода, електричество и нарастване на производствените разходи. Като се имат предвид отдалечеността на повечето работни площадки в Австралия [2,6], осигуряването на необходимите количества мощност и чиста вода за водните процеси при обогатяването може да се окаже трудно. HAVER&TYLER е известна по цял свят с технологията си за пресяване по сух и мокър начин. Иновативната система Hydro-Clean® е технология, която може да предложи икономичен и екологичен начин за пречистване на необогатена руда и смеси, с размер на зърната от 0–150mm, замърсени с адхезивни глини, прорези и други примеси.

Introduction

High-end steel production at a low coke consumption level and a high productivity rate can only be achieved by using high-quality, lumpy iron ore. As more pellets and sinter are used in the blast furnace burden, leading to an increase in the quality restrictions for sinter fines and concentrate for pellets, economical beneficiation processes become more important. While some iron ore companies are already marketing the 'green' iron ore pellet, other mining companies have only just commenced development of beneficiation processes for their production sites.

For a high-grade iron ore deposit, >62%, a dry crushing and sizing process is sufficient to achieve the required product quality and size fraction as lump ore, sponge ore or sinter fines. Other deposits with lower ore quality, <58%, could use selective mining and blending methods to achieve nominated grade targets, but today's quality restrictions often require advanced processing and beneficiation such as washing, separation and concentrating.

A beneficiation process to increase product quality is, by its nature, related to capital investment, and operational costs for the core equipment need to be considered. An influencing factor of further importance is water and tailings management, with its associated costs and risks.

Iron ore producers with high mine operating costs may suffer from a low iron ore price on the spot markets in China. Beneficiation, particularly washing (scrubbing), can be the key to upgrading the ore to earn more per shipped tonne.

Depending on the ore type, quality and its degree of degradation, a washing and classifying plant can increase the iron content by 2–5%, while reducing the silica, alumina, titanium oxide, sulphur and phosphorous content through removal of fines below 0.063mm by washing. For example, decreasing the alumina content reduces the blast furnace coke consumption level, while increasing the productivity and reducing the consumption of flux.

To increase the iron ore quality, it is necessary to liberate soft and friable lateritic masses, fine sand and limonitic clay particles adhering to lumpy ore. This may also be required for iron ores which consist of coarse and fine granular particles of hematite intermixed with barren sand or sticky limonitic clay, or in hard and porous hematite lumps, which invariably have cavities / pores filled with goethite / limonite and lateritic clay-like materials that need substantial elimination [1].

Scrubber drums, log washers or screw washers are commonly used in the industry today. These machines consume high volumes of water and energy. High-pressure washing with a HAVER Hydro-Clean® could offer an opportunity to save approximately 50% water and 10% energy compared to the traditional washing systems, whilst also reducing the capital and operational costs.

The small footprint and the low weight of the HAVER Hydro-Clean® compared to the traditional washing equipment create new opportunities and support innovative ideas in mining by making semi-mobile or completely-mobile units on trailers technically and economically feasible.

This paper presents a theoretical comparison of an iron ore washing process using a traditional drum scrubber system and a HAVER Hydro-Clean® high-pressure washing system. It delivers a high-level overview addressing water usage, energy usage, product quality and potential value for the user, underpinned with results from the HAVER Hydro-Clean® lab and pilot scale test works.

Fundamentals of washing processes

Run of mine material (ROM) consists mainly of two components – usable material and impurities. In hard rock and unconsolidated rock processing, impurities consist of clay-like and loamy components – fine particles with a grain size < 63µm. Different types of impurities occur within the feed material. They are either loose between the usable particles, binders, coatings, agglomerates or concrescences (Fig. 1).

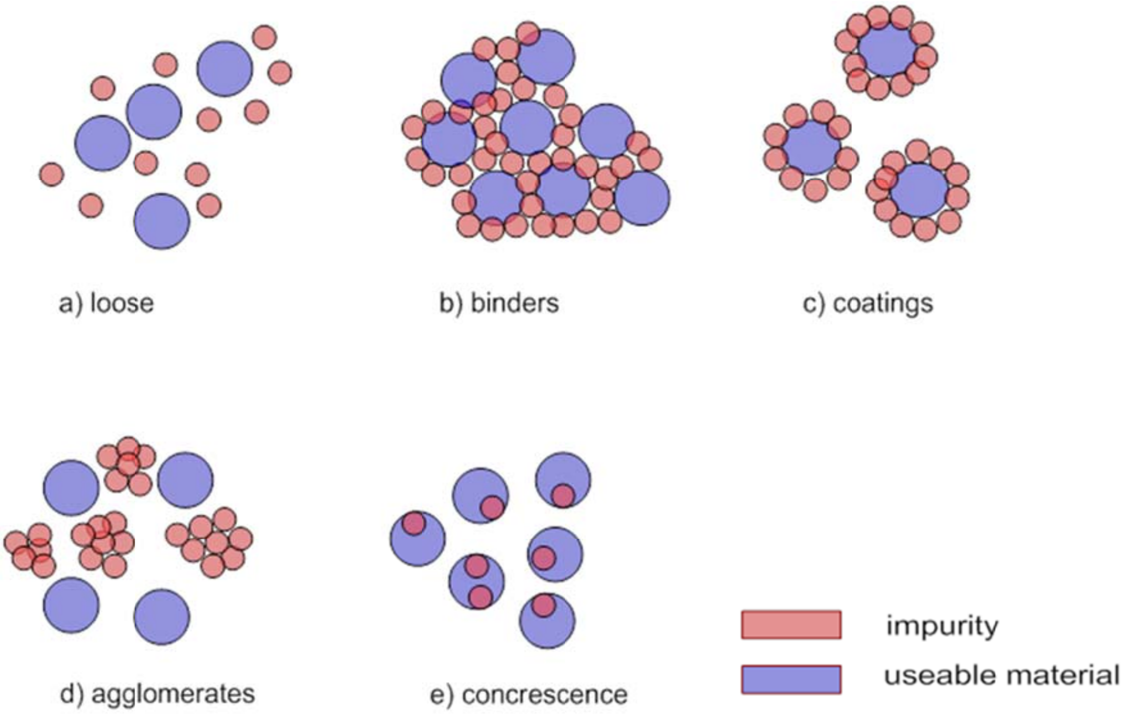


Fig. 1. Binding types of particles and agglomerates

The bonding forces between the particles are affected by attracting forces between the grains, e.g. capillary forces from fluid bridges, solid bridges and van-der-Waals forces between the grains. Washing processes apply energy in the material bed to dissolve these bonding forces. By these means, the impurities are suspended in water and can be separated in a classification or separation process. During the washing process, only a certain amount of energy should be applied – sufficient to loosen the bonding forces and low enough not to comminute the materials or create unnecessary wear.

The variables influencing the washing process are retention time and energy intensity. The energy input results from the product of both variables:

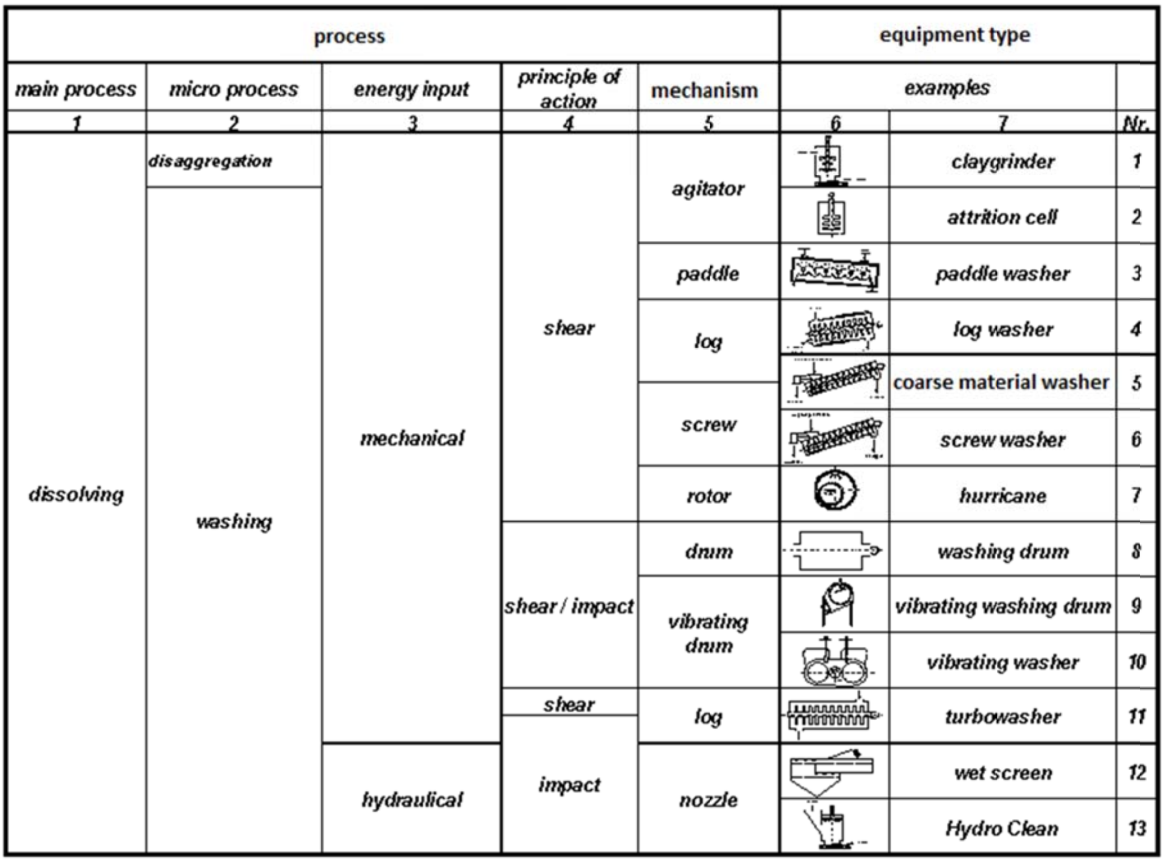
Energy input = retention time x energy intensity [Ws]

The success of the washing process is bound to the interaction of the variables. For optimal washing results, minimum values for retention time and energy intensity are necessary, but these values depend on the specific granulometrical, mechanical, chemical and mineralogical properties of the usable material and the impurities. [3]

SYSTEMATICS OF WASHING MACHINES

A global analysis of the function and construction of the main washing technologies differentiated between two groups of stress in the washers: impact stress and shearing stress. As the result of this analysis, a construction catalogue was developed where the majority of washing machines were listed and classified.

The construction catalogue (Fig. 2) consists of two parts: process and equipment. In the former, the machines are differentiated by their main and micro processes, the form of energy input and mechanisms. In the latter, a schematic diagram of equipment, a name and a numeration are given.



process					equipment type		
main process	*micro process*	*energy input*	*principle of action*	mechanism	*examples*		
1	*2*	*3*	*4*	*5*	*6*	*7*	*Nr.*
dissolving	*disaggregation*	*mechanical*	*shear*	*agitator*		*claygrinder*	*1*
	washing					*attrition cell*	2
				paddle		*paddle washer*	3
				log		*log washer*	4
				screw		coarse material washer	5
						screw washer	6
				rotor		*hurricane*	7
			shear / impact	*drum*		*washing drum*	8
				vibrating drum		*vibrating washing drum*	9
						vibrating washer	*10*
			shear	*log*		*turbowasher*	*11*
		hydraulical	*impact*	*nozzle*		*wet screen*	*12*
						Hydro Clean	*13*

Fig. 2. Schematic diagram of washing equipment

Scrubber drums are based on shearing stress, where the material is stressed by the rotation of the active mechanical component. A shearing stress between the feed material and the washer tub occurs. Due to friction between the particle surfaces, agglomerations and impurities associated with clay and loam are dis-agglomerated and their bonding forces are dissolved. The simultaneous flow of water and feed material through the process area enables the dispersion of the fine particles in water and their classification. The retention time is determined by the length of the washer tube. Retention time may be varied by adjusting the inclination angle.

In contrast to machines operating with shearing stress, machines operating with impact stress use impact or compressive forces to dissolve the bonding forces. Impact and compressive forces differ in their stressing speed. In these machines, either hydraulic or mechanical energy is applied to the material. In the vibrating washing drum, exciters generate a high-force, vibrating action, resulting in an intensive scrubbing process.
High-pressure water jets are used to apply hydraulic energy. In this case, the individual water drops act as the 'action tool'. Depending on the water pressure, very high stressing speeds can be achieved. In these cases, the retention time is a result of either the length of the washer tube or the speed of the discharge belt, as in in the case of the HAVER Hydro-Clean®. [3]

A comparison of the different machine types can be made with the help of independent classification numbers. According to Hoeffl [8], the following technical / economical classification numbers are used:

Specific power consumption: W = installed power [kW] / feed rate [t/h]
Specific water consumption: H = water amount [qm/h] / feed rate [t/h]
Specific energy density: E = installed power [kW] / machine volume [qm]

Technical description Hydro-clean® wash machine

The HAVER Hydro-Clean® is completely new machine technology for the mineral processing industry, although water-jet monitor guns have been used in commodities such as alluvial gold, diamonds and emeralds [9]. The first application of the Hydro-Clean® was for washing aggregate minerals. Subsequent to this conventional application, today there are units in operation within the recycling industry (building rubble) and minerals industry (diamonds, gold, limestone and gypsum).

The newly developed HAVER Hydro-Clean® is a high-pressure washing system. It can be used for economical cleaning of sticky clay, soil and other impurities from raw material with a size fraction of 0–150mm. The water pressure is adjustable at the equipment and can reach up to 16,000 kPa with a water and energy consumption between 0.08–0.2 m^3/t and 0.28–0.56 kW/t of feed material. The intensity of water pressure and hydraulic force are determined beforehand and, in most cases, lie in the range of 6,000–16,000 kPa.

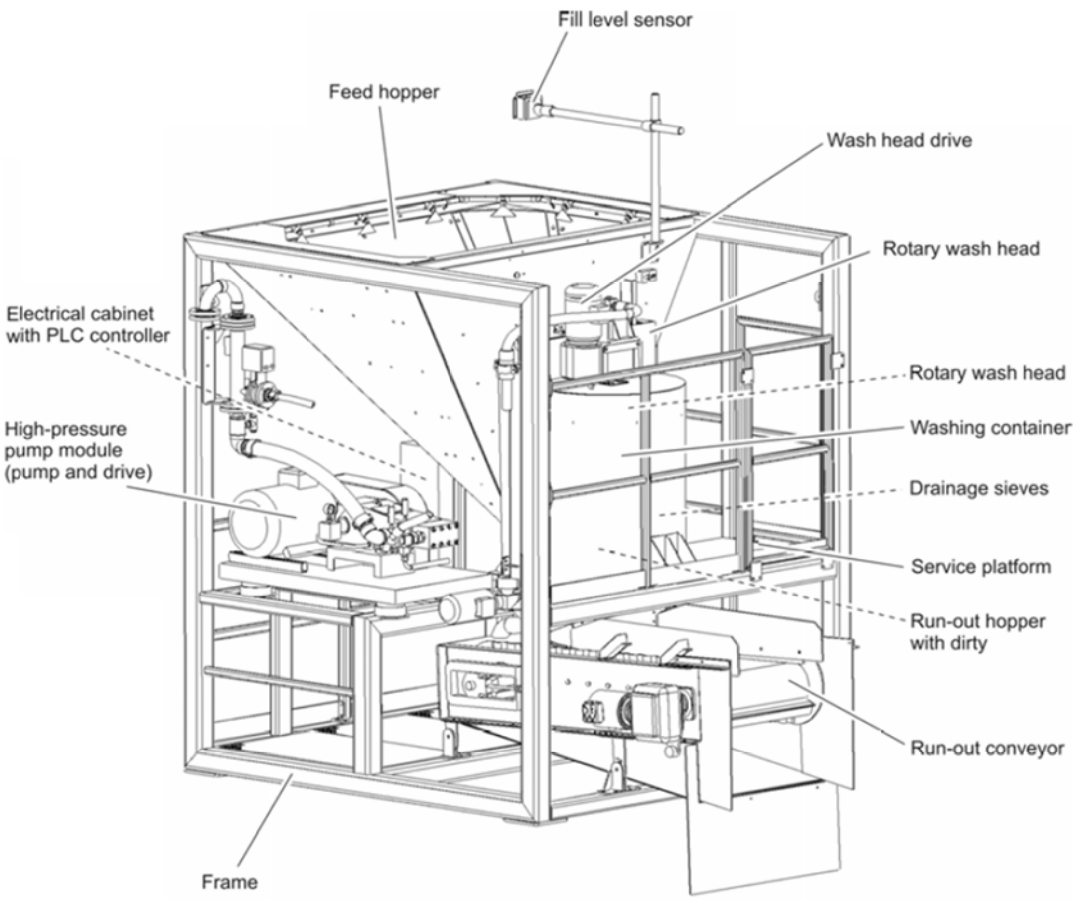


Fig. 3. HAVER Hydro-Clean® technical description

The HAVER Hydro-Clean® (Fig. 3) consists of a vertical washing drum, which has a feed hopper mounted on one side and a discharge conveyor belt on the other. The washing chamber, the central element of the HAVER Hydro-Clean®, consists of an upright cylinder which is lined with polyurethane panels. The washing chamber contains a rotor, which is mounted on its top side and consists of several water nozzles.

Some additional features of the HAVER Hydro-Clean® include the variable height adjustment at the rotary wash head, the discharge belt and the controlled feeding system that can be optimally adjusted to the bulk material and can produce outstanding washing results.

The HAVER Hydro-Clean® mode of operation begins with the material being continuously fed by a conveyor belt into the feed hopper. Small water jets are mounted on the side wall of the hopper, creating a low pressure downstream current, which helps the material, particularly sticky material, to flow into the washing chamber. The height of the material in the hopper is constantly monitored by a laser level indicator. From there the material passes a slide gate into the washing container and forms a column of material. The material is cleaned by being exposed to high-pressure streams of water that come from the washing rotor and spray nozzle combination, located on the top third of the cylinder. Water jets strike with a speed of up to 200 km/h on the particle surfaces. The nozzles are adjustable. When they are positioned in the movement direction of the rotor, the water distributed to the reactor is forced through the material, creating a ploughing effect. The cleaning process is assisted by the friction and sheer forces resulting from the material movement around the chamber in a vortex. Liberated fines material and process water are discharged from the washing chamber through the openings in the polyurethane panels at the side and are collected by a waste water pipe. The waste water discharge is sent for water treatment or further processing. The washed material passes through the run out hopper onto the variable speed discharge conveyor and is sent to a washing screen where the dis-agglomerated contamination is rinsed off.

The above process makes the HAVER Hydro-Clean® different from all washing technologies available in the market. Its ability to incorporate automation through advanced programmable logic controller makes it the most technologically advanced machine in the washing market today. [3]

Laboratory test works

To determine the general feasibility of high pressure washing for a certain material, HAVER developed the laboratory scale test unit: Hydro-Clean® 200 Lab (Fig. 4). The Hydro-Clean® test unit treats a material sample in a similar way to the industrial scale process by using a high-pressure water jet. A sample is placed on a stack of two wire mesh sieves with top size of 2mm and bottom 0.8mm to allow the water and liberated fines to rinse through while washing. The stack with the sample sits in an acrylic-glass covered process chamber.

In the top of the process chamber, above the material sample, a rotating, high-pressure nozzle is installed and connected to a high-pressure water pump delivering up to 16,000 kPa water pressure. It is possible to adjust pressure level and retention time parameters.

To demonstrate the effect of high-pressure washing on iron ore, a material sample 0–10mm was taken from a dry screening plant and split into representative samples for testing. Some physical properties, such as grain size distribution, bulk density, moisture content, and visual description (Fig. 5), chemical characteristics such as loss of ignition (LOI) and a generous element analysis were determined to aid interpretation of correlations between material pre- and post-treatment.

The target of the washing tests was to liberate the impurities from the valuable material (substrate) by de-agglomeration, disintegration and elimination of fines bonded to the material surface and cavities / pores. The test series, at a pressure level of 14,000 kPa, was carried out at two retention times: 6 and 12 seconds.

Fig. 4. HAVER Hydro-Clean® 200 LAB

A visual examination of the particles of the unwashed dry material sample showed an irregular particle shape and surface structure with significant amounts of fines adhering to the rugged and edged surface.

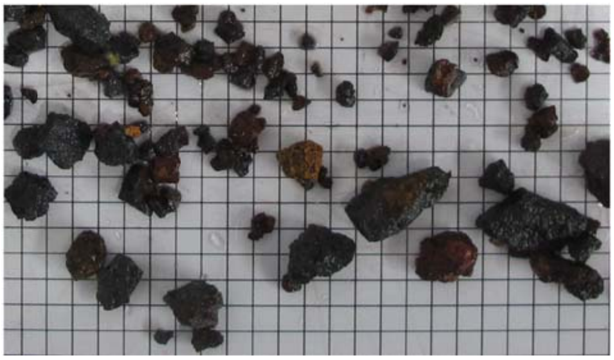


Fig. 5. Dry Material Sample 0 – 10 mm; Washed Material Sample 2 – 10 mm

A particle size distribution of the feed material (Fig. 6) was prepared as a dry and wet sieve analysis using a HAVER EML 200 test sieve shaker. These distributions showed that the feed material still contained 2–4% of free fines in a size –0.063mm and, in addition to this, about 7–10% of bonded fines –0.063mm.

The chemical analysis (table 1) of the feed material sample in a size of 0–10mm showed an iron (Fe) content of about 61.0%, silica (SiO_2) content of 4.5%, alumina (Al_2O_3) content of 3.2% and an LOI of 4.4%. The analysis of the fine fraction of –0.063mm presented an iron content of 52%, silica 8.1%, alumina 7.1% and an LOI of 6.4%.

Table 1. *Chemical analysis of dry feed fines and washed product*

	Fe	**SiO2**	**Al2O3**	**LOI**	**P2O5**
Dry Feed Material 0–10mm	60.87	4.42	3.15	4.38	0.04
Fines –0.063mm	52.32	8.12	7.18	6.44	0.04
Washed Material 2–10mm	64.39	2.52	1.97	3.34	0.01
Washed Fines 0.063–2mm	62.62	4.78	2.31	3.35	0.03

The material characteristic shows that the fine dry material 0–10mm contains up to 12% fines –0.063mm that has poor quality with a low iron content and high amounts of impurities as SiO^2 or Al^2O^3. Assuming the fines attached to the surface of the larger particles are responsible for the lower product quality of the dry fines 0–10mm, a liberation and elimination of those particles would increase the quality of the coarser particles.

The washed material appeared in two fractions on the Hydro-Clean® 200 Lab after the treatment: a top sample with a size of +2mm and a bottom sample with +0.8mm. Both fractions of all washing tests at 6 seconds and 12 seconds show a full liberation and elimination of fines (Fig. 7). The chemical analysis of the washed material samples shows a significantly higher amount of iron and a lower amount of impurities in the fraction 2–10mm compared to the dry feed material sample 0–10mm (Table 1). For the fraction 0.063–2mm the results are similar to the fraction 2–10mm, except silica, which is on the same level as the feed material.

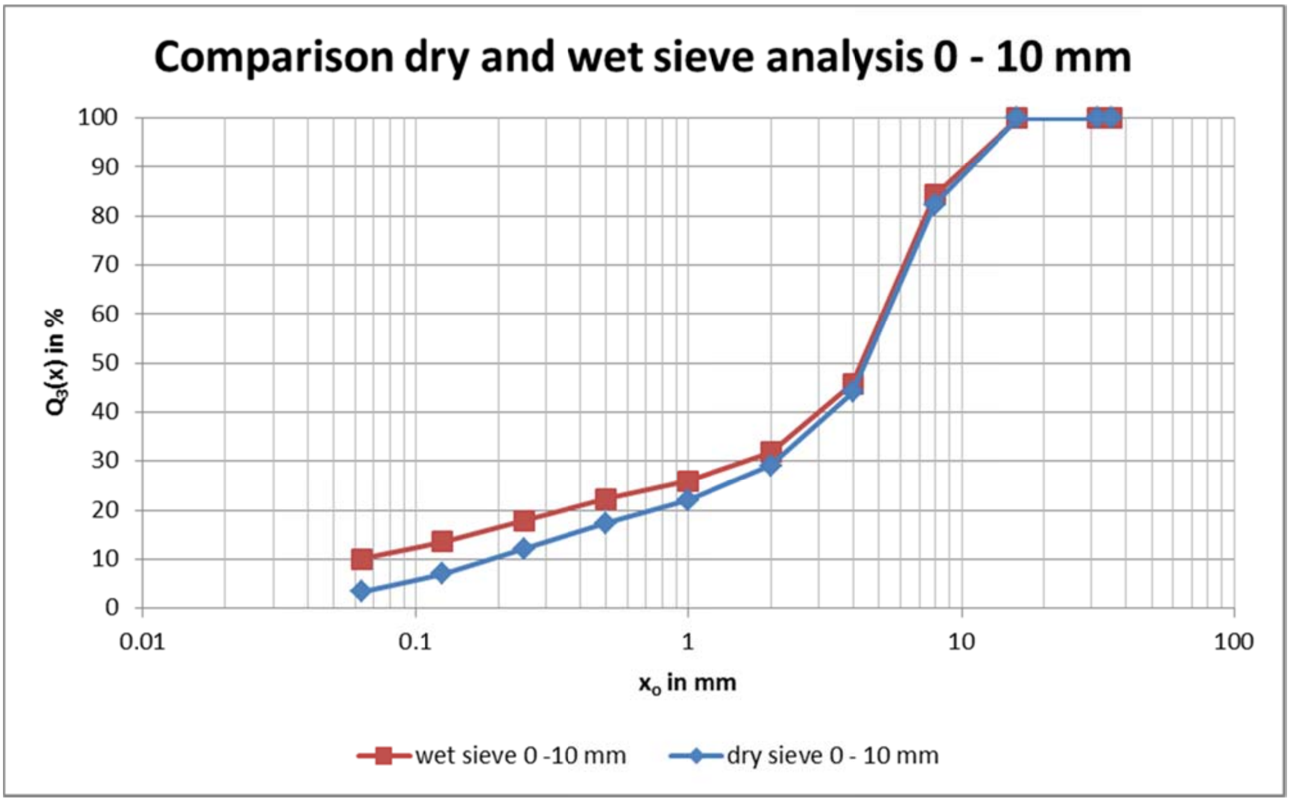


Fig. 6. Feed material grain size distribution, dry and wet sieve analysis

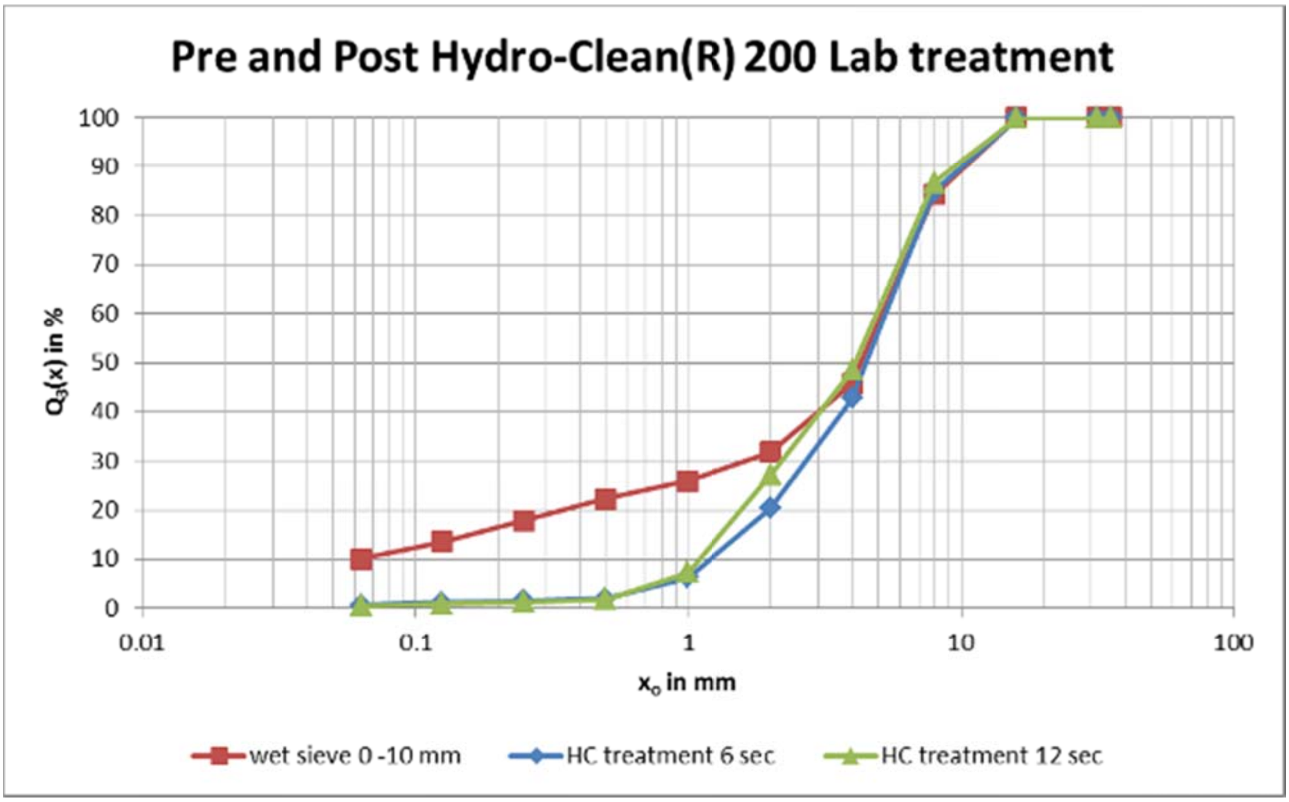


Fig. 7. Grain Size Distribution – Iron Ore Pre- and Post Hydro-Clean® Treatment

Based on a spot market price for an MBIOI-62 type iron ore from January 2015, the value-in-use for the washed material compared to the unwashed material would increase by approximately 11 US$ per shipped tonne [4, 5].

Pilot test works

If a laboratory-scale feasibility study shows positive results and evaluation of a business case demonstrates a benefit for an industrial-scale operation, a pilot scale test can be conducted. In such cases, a HAVER pilot test plant Hydro-

Clean® 350 with a capacity of up to 12t/h can be used to prove the functionality for a commercial-scale plant. The pilot test plant can be either a semi-mobile sea-container solution (Fig. 8) or fully-mobile on a trailer. Both test plant solutions consist of a Hydro-Clean® 350 high-pressure washing unit and a horizontal rinse screen with spray bars.

Fig. 8. Hydro-Clean® 350 semi-mobile pilot test plant

A stockpile of low quality, fine iron ore with an average iron content below 53% Fe in a size of 0–30mm (Fig. 9) was tested in a semi-mobile washing plant. The -0.063mm content of the feed material was about 20%, which included both free and bonded fine particles. The trial objective was to increase the iron content of the fraction in the size of 1–30mm and minimize the amount of SiO_2 and Al_2O_3. The test was conducted with a feed rate of 8t/h. The cut size on the rinse screen was 1mm.

Fig. 9. Iron Ore Fines 0 – 30 mm, left before washing, right after washing

A continuous test run demonstrated good liberation of fines and an increase of the iron content and elimination of SiO_2 and Al_2O_3 (TAB 2) in the washed material (Fig. 9). The chemical analysis of the washed material showed an average iron content of 58% and a significant decrease in Silica to approximately 4.5%. The washed material became a more valuable product [7].

Table 2. *Chemical analysis of dry feed and washed iron ore*

	Fe	**Al2O3**	**SiO2**
Dry Feed Material 0–30mm	52.8	2.2	11.5
Washed material 1–30mm, 8t/h	58.1	1.9	4.4

Iron ore process route with Hydro-clean®

In this theoretical scenario, a medium-grade hematite deposit with an average quality of about 58% Fe is chosen as an example. The maximum feed capacity of the plant is 800t/h.

The feed material characteristics, e.g. the clay content, vary with mined block location in the pit. The moisture content of the ROM fluctuates between 3 and 8% depending on the seasonal weather conditions.

The chosen flow sheet (Fig. 10) consists of a heavy-duty feed hopper with an apron feeder. As the feed material can contain up to 35% of fines 0–10mm, a scalping step based on a HAVER F-Class DS with a double deck conFig.uration of 150mm top deck and 10mm bottom deck is selected to relieve the crusher and produce a fine product cut size with 0–10mm on one machine.

The oversize material 150–1000mm is crushed in a jaw crusher with 100mm closed gab. The crushed material is then sent to a HAVER F-Class D with a double deck conFig.uration with negative screening setup on the second deck. The top deck cut size is 80mm and is used as a relief deck. That material is sent to a secondary crushing circuit together with the oversize material from the bottom deck. The bottom deck creates two products at the same time: one fine product in a size of 0–10mm in the first part of the screen deck and 10–35mm lump size material in the second part of the screen.

The secondary comminution process uses a cone crusher with a 38mm gap in a closed circuit with a HAVER F – Class D with a two deck conFig.uration. The oversize material 35-80mm from the top deck is sent directly back to the cone crusher. The bottom deck delivers a lump ore product of 10–35mm and, as undersize, a sinter fines product measuring 0–10mm.

The lump ore stream 10–35mm and the fine ore stream 0–10mm can be sent either to a washing plant for further upgrading, or, if the quality is high and no processing is required, the material stream can be sent to the product stockpile.

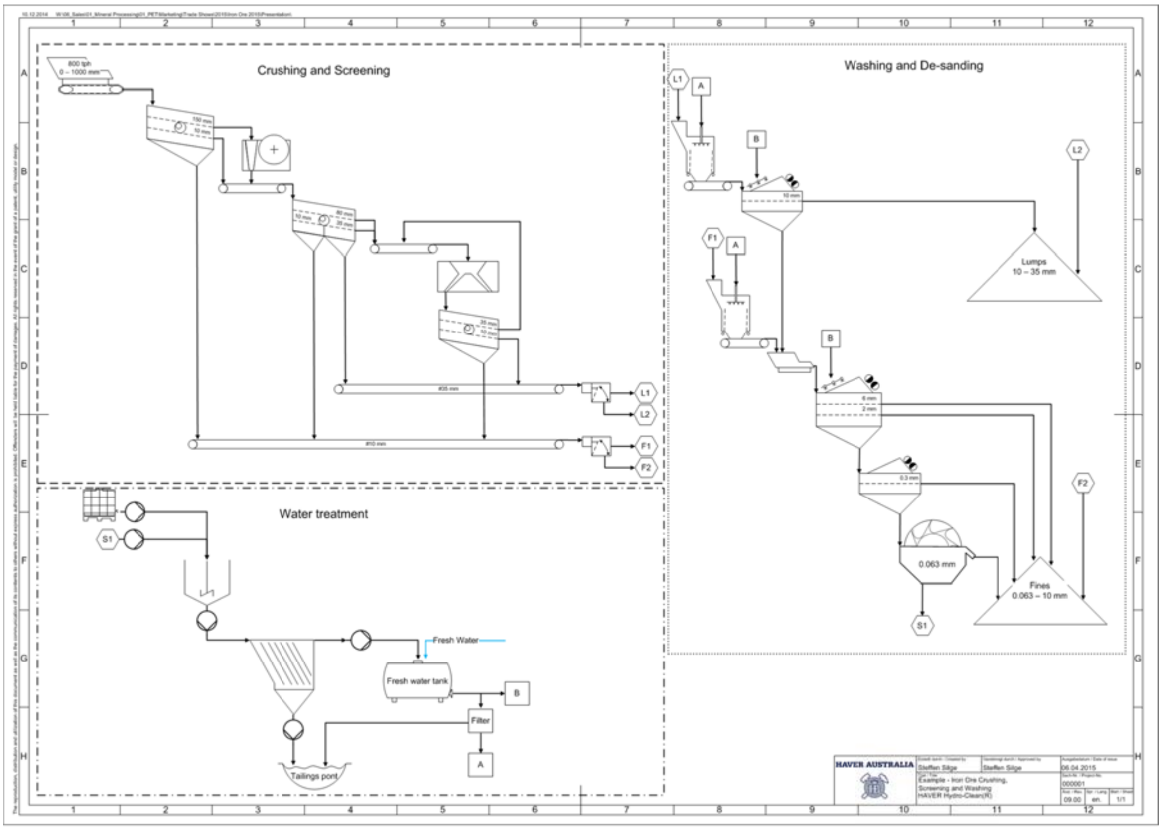


Fig. 10. Flow sheet of a 5.000.000 t/an iron ore operation with HAVER Hydro-Clean®

The washing plant consists of two HAVER Hydro-Clean® 2000 high-pressure washing units: one for the lump ore and one for the fine ore. Both washing units are designed for a maximum capacity of 400t/h consuming 45m^3/h water. For the lump ore material, the washed material and the wash water are discharged onto a HAVER XL – Class rinse screen with a one deck set up at a cut size of 10mm and three spray bars on the top deck with a water consumption of up to 150m^3/h. The oversize material is an upgraded lump ore that is transferred to the stockpile as a product. The undersize material and most of the wash water flows to the product screen for washing of the sinter fines, using gravity to support the rinse effect of the screen. For the sinter fines material, a HAVER XL-Class rinse screen with a two deck set up and three spray bars on the top deck with a water consumption of up to 100 m^3/h is used. The top deck works as a relief deck with a cut size of 5mm while the bottom deck prepares the fine cut at 2mm. The oversize material of the top deck and bottom deck are taken to the stockpile as an upgraded product.

The tailings from the primary washing and rinsing process consisting of the undersize material –2 mm of 120t/h and the wash and rinse water from the prior process of about 280m^3/h could then be treated further in additional beneficiation steps. This could be done in a sand recovery system to recover the fine fraction between a size of –0.063mm and 2mm using a dewatering screen with a cut size of 0.3mm in combination with a bucket wheel. Using a dewatering screen before the bucket wheel reduces the total solid mass transport in the tailings stream to 60t/h and the volume flow to 270m^3/h.

The 260m^3/h overflow water from the bucket wheel still carries fine material in a size fraction –0.063mm. That can then be directed to a further processing step using a waste water treatment system, including a flocculation system combined with a lamella clarifier to recycle the water back into the primary washing and rinsing process.

The thickened tailings from the lamellar clarifier are pumped to a tailings pond for further settling. The clarified water is pumped to a recycling water tank where fresh water is added to compensate for water losses during processing. The tank water may be directly used on the rinse screens, whilst the water for the Hydro-Clean® is filtered before it enters the high-pressure pumps to minimize wear and tear.

Comparison Hydro-clean® VS. Scrubber drum

By exchanging traditional scrubber drums with Hydro-Clean® washing units, several benefits in the process and plant layout can be achieved. A direct comparison of a Hydro-Clean® and a Drum Scrubber (Table 3) points out the major differences of both systems.

For the process scenario described above, the total calculated water flow using two drum scrubbers and two rinse screens is 800m^3/h for processing 800t/h of ore. The balance sheet using two Hydro-Clean® washers and the required screens requires 390m^3/h water for 800t/h of ore. The Hydro-Clean® process requires 354kW while the process using scrubber drums need 344kW. The specific water consumption of the Hydro-Clean® in combination with the rinse screen can be considered as 0.49m^3/t compared to 1m^3/t with the scrubber drum setup.

Table 3. *Comparison of one drum scrubber, one Hydro-Clean® unit and one rinse screen, process related data*

Unit	**Drum Scrubber**	**Hydro-Clean®**	**Rinse screen**
Solid Feed Capacity [t/h]	400	400	400
Retention Time [sec]	180	3	60
Wash Water Consumption [m^3/h]	250	45	150
Specific Water Consumption [m^3/t]	0.63	0.11	0.38
Installed Power [kW]	135	140	37
Specific Energy Consumption [kW/t]	0.34	0.35	0.09

Fig. 11. Sand Recovery System: left Hydro Cyclons in combination with Dewatering Screens, right Bucket Wheel

Saving water in the washing process can lead to several further potential savings along the process chain. For a sand recovery system, using less water makes it possible, for example, to use a bucket wheel (FIG. 11). The calculated settlement area for a bucket wheel using the Hydro-Clean® process which requires 390 m3/h of water is 24m2 compared to 50m2 using drum scrubbers requiring 800m3/h. That qualifies the Hydro-Clean® process for using a bucket wheel and disqualifies the use for the drum scrubber application, thus another sand recovery system needs to be chosen. A common method is the use of hydrocyclones in a closed circuit with dewatering screens (Fig. 11).

The energy consumption of a hydrocyclone in combination with a dewatering screen and the required pumps can be considered 144kW. The required energy for a dewatering screen and a bucket wheel for this application can be considered with 42kW installed power.

Table 4. *Comparison of hydrocyclones and bucket wheel, process related data*

Unit	**Hydrocyclone and Dewatering Screen**	**Dewatering Screen and Bucket Wheel**
Cut Size	0.063	0.063
Solid Feed Capacity [t/h]	120	120
Water Flow [m^3/h]	800	390
Installed Power [kW]	144	42
Specific Energy Consumption [kW/t]	1.2	0.35

Hence, in the sand recovery step, the Hydro-Clean® in combination with a bucket wheel requires about 92kW less power than the scrubber drum process with hydrocyclones.

Table 5. *Comparison of one drum scrubber, one Hydro-Clean® unit and one rinse screen, design related data*

Unit	**Drum Scrubber**	**Hydro-Clean®**	**Rinse screen**
Feed Size max. [mm]	360	150	100
Length [m]	10	4	6
Width [m]	4	4	2.8
Heights [m]	4	4	2.5
Volume [m³]	160	64	42
Specific Energy Density [kw/m³]	0.84	2.19	0.88
Static Weight empty [t]	40	10	16
Static Weight loaded [t]	85	15	25

The design schematic shows a total required build in volume for the two drum scrubber plus rinse screens of 395m^3 and a static weight in operation of 220t. Compared to the two Hydro-Clean® in combination with rinse screens, the build in volume is about half, with 204m^3, and a static weight in operation is about a third, with only 80t. This has an essential impact on the required steel structure of a building. Due to given facts, a semi-mobile or even fully-mobile plant with one or more drum scrubbers can only be considered using a heavy-duty steel construction, e.g. mounted on a caterpillar drive, while a Hydro-Clean® unit with rinse screen can be installed and operated on a standard truck trailer (Fig. 12).

Fig. 12. HAVER Hydro-Clean® 2000 mobile plant

CONCLUSIONS

A systematic overview of the available washing technologies in the market has been given. The laboratory and pilot scale test work results demonstrate the potential use in iron ore applications, with substantial cleaning results. The Hydro-Clean® process is an innovative alternative with significant water and energy saving potential compared to a common washing process with a drum scrubber. The compact and modular design of the Hydro-Clean® allows the construction of semi-mobile and fully-mobile plants or reduces required steelworks for a stationary plant.

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