7.2.27 Final pilot plant layout

Summary

Introduction

On the basis of the results of the additional lab-scale treatment runs (annex 7.2.11) and the suggestions received from the industrial producer of the pilot plant units, an improved process layout for the pilot plant was designed. This implied some changes in the process sequence and plant structure with regard to what initially decided on the basis of the results from the first lab-scale testing campaign. It is believed that the final plant layout that has been setup is more reliable for practical applications, since it has been adapted to the range of sediment characteristics analyzed during actions 3.1 and 3.2 and has been improved in terms of applicability at larger scales.
In the following sections, a synthesis of the evolution in the pilot plant layout is illustrated.

Pilot plant layout based on the results from lab-scale treatment runs

On the basis of the results of the separation treatment runs performed during the year 2011 and of the attrition treatment carried out on recovered sand fraction of the POCES3 sample, a first pilot plant layout was proposed by UNICA and discussed with the other partners.
The general characteristics, as suggested by the treatment runs performed at the laboratory scale, are the following:

- a first screening section for the removal of the coarser particles (> 4-5 mm)
- a spiral classifier for the separation of the recoverable sand (4-0.063 mm)
- an attrition cell to reduce the content of pollutants in the recovered sand (when required)
- a secondary screening unit aimed at further separating coarse particles (> 2 mm) from the recovered sand;
- a hydrocyclone to be used (if required) for recovering fine sand from the fine particle flow (overflow of the spiral classifier)
- a dewatering unit to be used for reducing the water content of the fine particles.

Screening is defined as a mechanical process which accomplishes a separation of particles on the basis of size and their acceptance or rejection by a screening surface. Particles are presented to apertures in a screening surface and rejected if larger than the opening or accepted and passed through if smaller. Therefore, screens are machines used to classify materials by size and are used also for dewatering, desliming, media recovery, scalping, trash removal, washing, dedusting, concentration and many combinations of these functions. Of course, among the industries that employ screens are natural resource companies producing sand and gravel. The key element in all screens is the screening surface or screening media. This is where the real work of separation is accomplished. For most mechanical screens, to permit the use of light and thin screening surfaces, a support frame is installed directly below the screening surface. The weight of the bed is thus transferred to the support frame and then to the base frame.
A spiral classifier consists of an inclined tank in which one or two spirals revolve slowly and freely without touching the sides or bottom of the tank. The device results in solids classifications according to size or density through the different settling rates of the particles in suspension. It is a simple, rugged and easily maintained device capable of maintaining fine particles in suspension (overflow) and simultaneously draining and conveying the coarse particles (sand) out of the classifier. The tank is equipped with an overflow weir and an overflow box for collecting the overflow product which generally consists of fine solids and water. The feed enters through an

opening at one or both sides of the tank. The settled product is discharged at the upper end of the tank by the revolving spiral or, in the duplex configuration (double spiral), is conveyed up the center of the tank between the two spirals. Classification at a particular particle size is accomplished by gently introducing a slurry into the classifier pool. Minimal turbulence at the entry point promotes predictable settling rates, therefore the use of a feeder box is advisable. For the sediments under concern, spiral classification should produce the fractions -4 +0.063 mm and the -0.063 mm; with respect to the technical goals of the project (producing clean sand from the sediment), this should be the pivotal phase of the whole treatment process.
The basic feature of attrition machines is achieved by the energy implemented by a fluid or solid impeller. Attrition machines can produce very small size products and product size can be controlled within a narrow range. The mechanism depends on the type of attrition machine. In a sand grinder usually a circulating pattern subjects the solid particles to intense compressing and shear forces; the particles are brought into contact and the shearing action of the agitated sand is used to fracture crystals.
The hydrocyclone separates on particle size and specific density. In fact, a hydro-cyclone is a device to classify, separate or sort particles in a liquid suspension based on the ratio of their centripetal force to fluid resistance. This ratio is high for dense (where separation by density is required) and coarse (where separation by size is required) particles, and low for light and fine particles. A hydrocyclone normally has a cylindrical section at the top where liquid is being fed tangentially, and a conical base. The angle, and hence length of the conical section, plays a role in determining operating characteristics. A hydrocyclone has two exits: the smaller on the bottom (for the underflow or simply under) and a larger at the top (for the overflow or simply over). Internally, centrifugal force is countered by the resistance of the liquid, with the effect that larger or denser particles are transported to the wall for eventual exit at the underflow side with a limited amount of liquid, whilst the finer, or less dense particles, remain in the liquid and exit at the overflow side through a tube extending slightly into the body of the cyclone at the center. The underflow is thus generally the coarser or denser fraction, while the overflow is the finer or lighter fraction. In a suspension of particles with the same density, a relatively sharp cut by size can be made. The size at which the particles separate is a function of cyclone diameter, exit dimensions, feed pressure and the relative characteristics of the particles. Efficiency of separation is a function of the solids' concentration: the higher the concentration, the lower the efficiency of separation. Hydrocyclones can be made of metal, ceramic or plastic. Metal or ceramic hydrocyclones are used for situations requiring more strength, or durability in terms of heat or pressure. When there is an occurrence of much abrasion (such as occurs with sand particles in a sediment) plastic performs better than metals or ceramics.

On the basis of the project goal and of the characteristics of the treated sediment samples, the possible treatment scheme was proposed as described in the following.
The first treatment unit performs a coarse sieving (size of the sieve openings: 4-5 mm) in order to remove larger particles (undesired items, shells, stones, sea weeds) which could affect the performance of the following separation unit. The undersize fraction (< 4-5 mm) is fed to the following unit (spiral classifier) which represents the main section in view of sand recovery. The spiral classifier separates the -4 +0.063 mm (sand) from the fine fractions (<0.063 mm). The recovered sand is sent to a final storage tank.
If necessary, additional treatments can be applied in order improve the quality of the reusable material: i) further separation by sieving, if required through the same device used for the coarse sieving after changing the opening size from 4-5 to 2 mm, in order to reduce the content of organic materials (> 2 mm), ii) a dedicated treatment (attrition) aiming at reducing the presence of organic pollutants (if this is the case) in the recovered sand.
The fine fractions (<0.063 mm) are sent to a densifier plus a filter or to a centrifuge unit for dewatering and then to a final storage tank. Alternatively, a hydrocyclone may be used for the recovery of fine sand particles which may have not been separated by the spiral classifier.

Changes in pilot plant layout on account of the availability of the ISPRA pilot plant

In late 2011 it was clear that overcoming the numerous difficulties encountered by ICOP for pilot plant authorization at one of the originally selected harbors was strongly unlikely. As explained in detail in the MTR, it was proposed to explore the feasibility of installing the sediment treatment plant in the area owned by the Port Auhtority of Livorno where ISPRA had previously operated a simple pilot plant for sediment separation. This included:

1) a vibrating screen for separation of coarse fractions (> 4 mm) such as stones, shells, sea weeds, etc.; the screen was fed by a conveyor belt;
2) a sedimentation tank for separation of coarse and medium size sand (-4 mm +0.125 mm);
3) a hydrocyclone for separation of fine sand from the finer fractions (cut point: ~0.050 mm); the hydrocyclone was provided with a loading tank.

A schematic of the ISPRA pilot plant is shown in Figure 1.

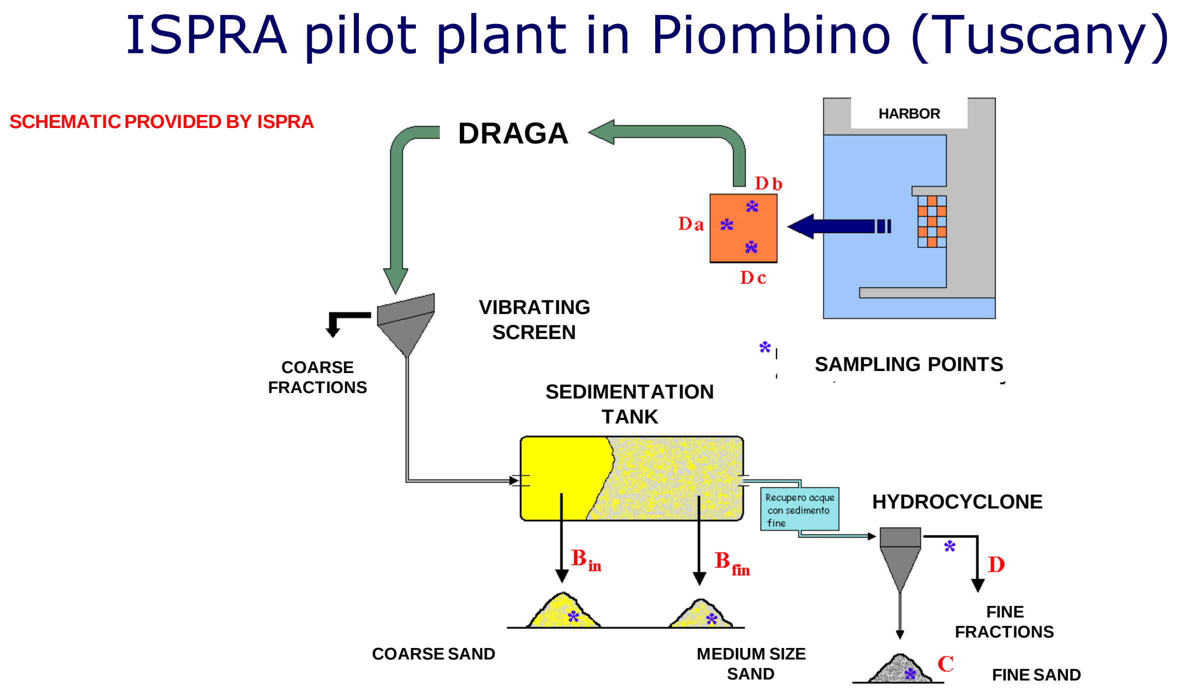

Figure 1 – Schematic of the ISPRA pilot plant in Piombino

The possibility of using (part of) the ISPRA pilot plant was explored and discussed. It was concluded that the above described pilot plant could in principle have been capable of treating dredged sediments to recover sand fractions to be used for beach nourishment.

However, as the pilot plant to be implemented in the framework of the project was intended for treatment of sediments of different characteristics and size distribution, an implementation of the existing ISPRA plant was judged to be required. On the basis of the findings from the lab-scale treatability tests performed by UNICA, the following considerations were done:

- the addition of a spiral classifier was judged to be necessary;
- the addition of an attrition cell to reduce (when required) the content of organic pollutants in the recovered sand was judged to be necessary;
- the addition of a second sieving unit to be used for sand refining was judged to be useful; this may either be an additional sieving unit with 2-mm openings, or may use the first screening unit simply replacing, on a need basis, the screening surface with one having a 2-mm mesh;
- some of the existing units of the ISPRA pilot plant appeared to fit well with the treatment train proposed for the POGAR, CERVIA, BELLARIA3 and POCES3 sediment samples; in particular, the vibrating screen (4-mm openings) and the hydrocyclone may be useful for separating the coarse fractions and recovering fine sand particles that may be present in the overflow of the spiral classifier, respectively (the latter as the underflow of the existing hydrocycloning unit).

In addition to the above mentioned main treatment units, further units which were judged to be necessary include:

- a temporary storage tank for dredged sediments;
- a temporary storage tank for the vibrating screen oversize (and, if required, for the oversize of the 2-mm refining sieve);
- a proper connection system between the existing vibrating screen and the spiral classifier;
- a loading tank for the spiral classifier;
- a storage/settling tank for the sand separated by the spiral classifier;
- a dewatering system for the fine fractions separated by the spiral classifier (or, if required, for fine sand and finer fractions as the hydrocyclone underflow and overflow, respectively)
- a final storage tank and related connections;
- a proper connection between the spiral classifier and the loading tank of the hydrocyclone.

Further development of the pilot plant layout

During the first months of 2012 a number of contacts were established with companies operating in the field of soil/sediment washing.

The goal was the exchange of technical information concerning the final pilot plant layout and the identification of a partner, in the form of sub-contractor (technical assistance), in change of implementing the proposed plant layout in terms of executive design and providing the required treatment units and auxiliary equipment.

After numerous contacts and share of technical information, ECOMIN Srl was selected as one having the required competences, with specific technical skills in environmental protection, materials recycling, as well as industrial production and supply of equipment and services in such fields. A specific meeting with the participation of IGAG-CNR, ICOP, ISPRA, UNICA, UROMA and Ecomin was arranged in Rome in June 2012 (see Figure 2) to define the final technical aspects related to the pilot plant layout and characteristics.

The improved final plant layout differs from the previously defined process scheme not for the type of treatment units, but for the adopted sequence of units and type of function accomplished. In particular, it was agreed that the attrition cell could be used either for the reduction of organic pollutants from the recovered sand (when required), or for breaking aggregates, thus improving the sand separation efficiency (see Figure 3); therefore, in this new configuration the attrition cell is not an optional unit but rather a main one.

The original concept of feeding the attrition cell only with the overflow of the spiral classifier was maintained, otherwise the fine particles may act as a lubricating medium and adversely affect the performance of the attrition treatment. The outflow of the attrition cell is sent, jointly with the fine particles separated by the spiral classifier, to the hydrocyclone in order to perform the final sand separation. Finally, the spiral classifier, rather than being the main section appointed to sand separation, would acts as a pre-treatment stage in view of attrition washing. The underflow of the hydrocyclone (sand fraction) is fed to a dewatering screen jointly with a portion of the overflow, the latter to be recirculated to the hydrocyclone.

Figure 2 –Technical meeting in Rome for the final definition of the pilot plant layout

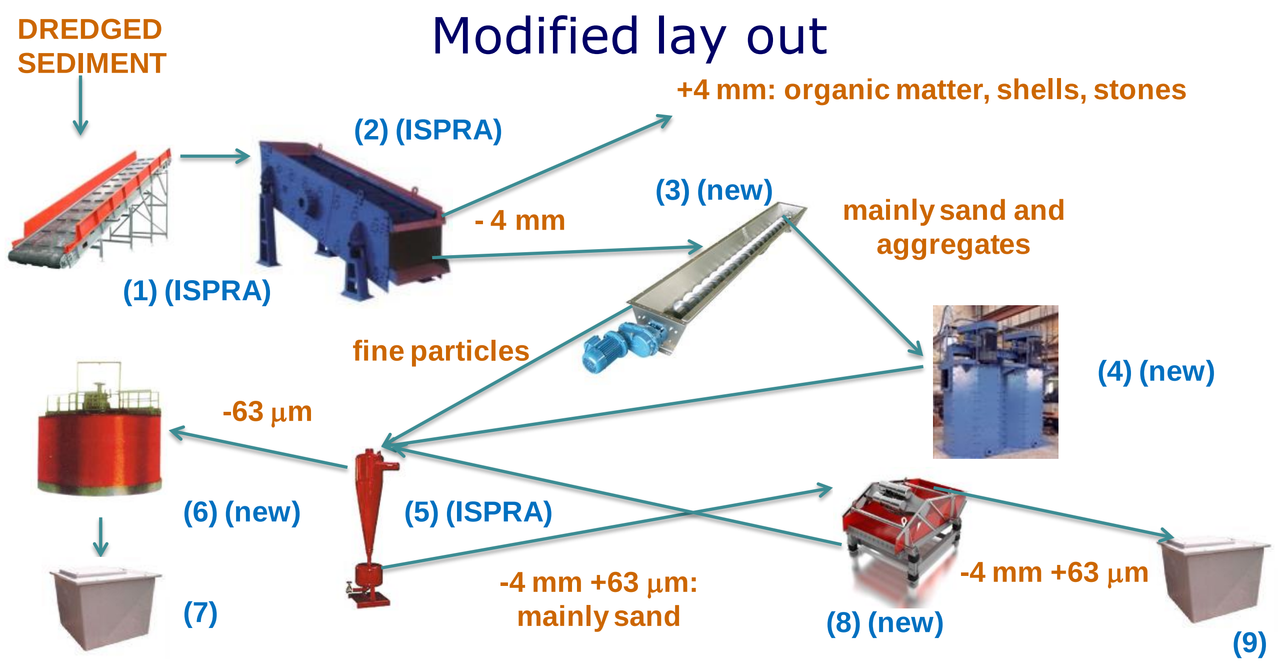

Figure 3 – Further development of the pilot plant layout: (1) existing belt conveyor; (2) existing vibrating screen for coarse sieving (4 mm); (3) spiral classifier (to be implemented); (4) treatment of the recovered sand (attrition) and aggregates breaking (to be implemented); (5) existing hydrocyclone for recovery of fine sand from the overflow of the spiral classifier; (6) densifier + filter or centrifuge for dewatering of fine fractions (to be implemented); (7) dewatered fine fractions final storage tank; (8) dewatering screen (to be implemented); (9) sand final storage/settling tank

Final pilot plant lay-out

Further technical discussions with ECOMIN and the possibility of visually inspecting the dredged sediments resulted in the final improved pilot plant layout. The main technical issues which led to the final configuration were the following:

- in general, it was acknowledged that the layout should be characterized by technical flexibility in order to allow for the treatment of sediments of different characteristics; this figure was taken into account also in view of further applications of the pilot plant;
- the visual observation of the dredged sediments stored at the Livorno harbor indicated that the size of the coarser particles was smaller than expected, in particular with reference to > 2 mm particles; therefore, it was decided to reduce the openings of the preliminary screening unit from 4-5 mm to 2 mm.
- it was found that the hydrocyclone of the existing ISPRA pilot plant was in bad conditions, so that it need to be replaced by a new one
- it was decided to avoid the use of belt feeder, to be more conveniently replaced by a bobcat.

On the basis of the above mentioned considerations, the final improved plant layout as shown in Figure 4 was defined.

Given the negligible content of particles > 4 mm, it was considered possible to feed the preliminary screen (2) undersize (< 2 mm) directly to a hydrocyclone (3) without passing through the spiral classifier; through the hydrocyclone the separation of most of the fine particles (hydrocyclone overflow) is accomplished. The hydrocyclone underflow goes to the attrition cell (4) in order to break the aggregates and (if required) reduce the organic contaminants content in sand; the performance of the attrition cell benefits from the separation of the fine particles previously performed by the hydrocyclone (3). The outflow of the attrition cell is fed to the spiral classifier (5) through which the separation of -2 mm +0.6 mm sand particles (spiral classifier underflow) is accomplished; the overflow of the spiral classifier goes, together with the hydrocyclone overflow, to a second hydrocyclone (7) where the recovery, as under, of the fine sand (- 0.6 mm + 0.063 mm, if any) is carried out.

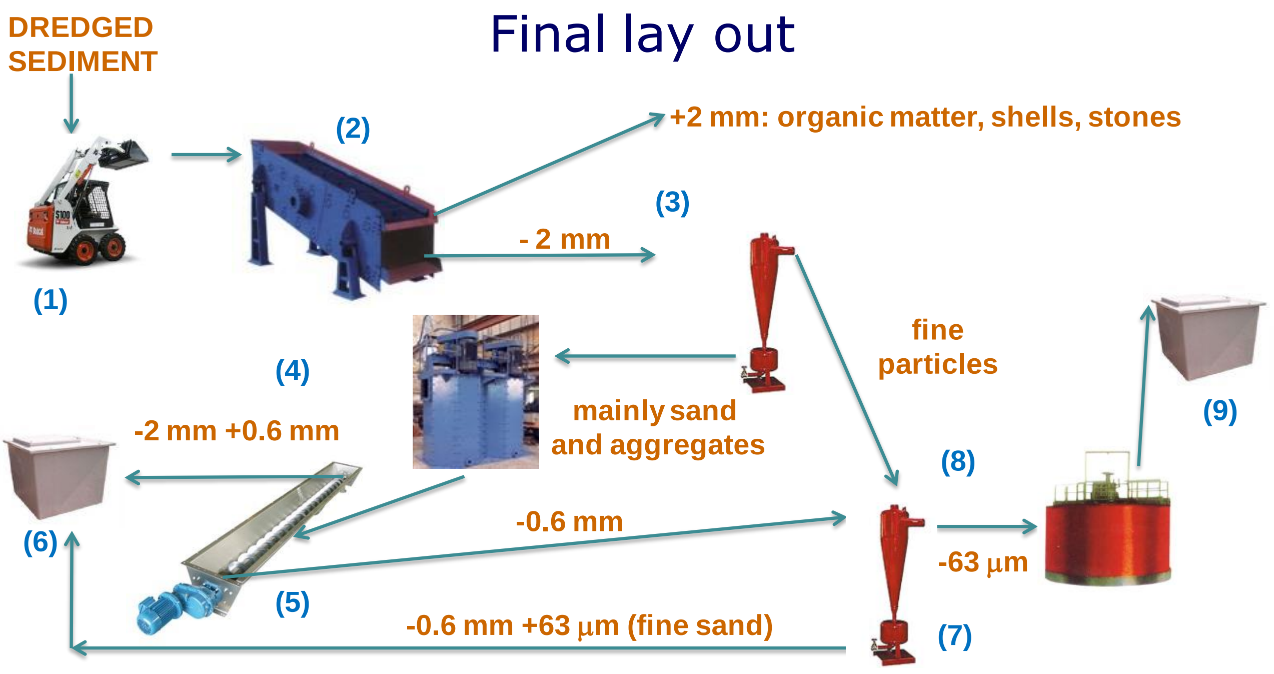

Figure 4 –Final improved pilot plant layout: (1) bobcat loader; (2) vibrating screen for preliminary sieving (2 mm); (3) first hydrocyclone for the separation of fine particles; (4) treatment of the recovered sand (attrition) and aggregates breaking; (5) spiral classifier; (6); sand final storage/settling tank; (7) second hydrocyclone for recovery of fine sand from the overflows of the spiral classifier and of the first hydrocyclone; (8) densifier + filter or centrifuge for dewatering of fine fractions; (9) dewatered fine fractions final storage tank.