NEW DEVELOPMENTS IN BEACH CLEANUP TECHNIQUES

Richard Pasquet and Jacques Denis
CEDRE
BP 308, 29274 Brest, France

ABSTRACT: *French coasts have been polluted several times by oil, and intensive cleanup was necessary to restore the hundreds of kilometers of contaminated shore. The spills provided a wide field of experiences for beach cleanup techniques. Only human labor or usual public works and agricultural equipment were available, and all of them were limited either in the quantity or selectivity of wastes collected.*

The Centre de Documentation de Recherche et d'Expérimentations sur les Pollutions accidentelles des eaux (CEDRE) started working in 1979 to develop equipment with better performance. First, it investigated existing equipment, and particularly agricultural technology, for its versatility and ability to work on smooth soils. Then it compared the performances of several beach cleaners used to pick up litter and seaweed during the summer. CEDRE finally decided to improve one of these beach cleaners by adding a "kit" for use on agglomerated oil. This kit now is available and has been tested successfully in the field.

But no existing equipment was found to be really effective on fresh oil stranded on shore. Therefore, three years of hard work were devoted to the development of another new piece of equipment which has been tested in the field and now is available. It is a specific type of drum, lined with a collecting material which can recover a layer of oil on sand, with the oil reaching 50 percent in volume. The wastes are transferred immediately to an agricultural vehicle or a dump truck.

Several units of each of these two types of equipment will be bought by French authorities.

In spite of all the efforts to avoid it, oil often reaches the shoreline and the beach must be cleaned to restore economic and ecological activities. This cleanup involves picking up and handling great amounts of sandy wastes and generally is performed by traditional means like public works equipment or by manual labor. Many experiences in the past have shown that these techniques, in spite of their availability and their simplicity, did not meet all the necessary requirements.

As little work had been done on this matter, the Centre de Documentation de Recherche et d'Expérimentations sur les Pollutions accidentelles des eaux (CEDRE) was asked by French authorities to evaluate beach cleanup techniques. This evaluation, based on the experience gained from the *Amoco Cadiz* (Table 1) and the *Tanio* spill, finally pointed out the necessity of more selective oil recovery equipment.

Analysis of cleanup methods

When oil reaches the shoreline in large amounts, it is impossible to avoid damage to amenities and ecosystems, and often it is difficult to restore oiled areas to their original state. The aims of beach cleanup are to limit these damages and to restore the polluted areas to a state compatible with their use.

The first operation, which is decisive in the final result, is the quick recovery of the stranded oil. That will limit the time of contact between the pollutant and the coastal ecosystem as well as the geographical extent of the contamination by avoiding a possible return of the oil to sea, its drifting under winds and currents, and its washing ashore in unpolluted areas. This quick response does not justify that the oil must always be recovered under any condition and with any equipment.

Evaluation criteria. A recovery method for beach cleanup must be evaluated under several criteria, including:

- Productivity, that is, the quantity of wastes collected per unit of time—The rapidity of the collection is an important factor in limiting the extent of damage caused by the oil.
- Impact on ecosystems—Very productive equipment may be detrimental to the ecosystem and the shore sedimentological equilibrium if the oil is buried and deeply mixed with sand.
- Selectivity, that is, quantity of oil collected in the wastes—The disposal of collected wastes often is difficult and expensive. Moreover, beaches often do not have enough sand, so as little as possible should be removed and then replaced.
- Effectiveness on both fresh and weathered oil, light or viscous
- Accessibility to the coast—Even if equipment is effective, it will not be used if it cannot have access to beaches and its use is not recom-

Table 1. Analysis of the *Amoco Cadiz* beach cleanup (1978 costs)

	Collected material (per day)	Oil content (%)	Costs[1] Collected material	Costs[1] Recovered oil	Remarks
Manual labor					
• in bulk	2 m^3 per person	5 to 10	200 FF/m^3	2,000 to 4,000 FF/m^3	Used a loader to remove bulk
• in bags	1 m^3 per person	5 to 10	375 FF/m^3	3,750 to 7,500 FF/m^3	material or bags (*1 for 100*)
Mechanical pick up					
• front end loader and truck	100 to 180 m^3	1 to 5	20 to 35 FF/m^3	400 to 3,500 FF/m^3	Used only for important and continuous slicks
• grader, loader and truck	180 m^3	1 to 5	30 FF/m^3	1,000 to 3,000 FF/m^3	Used for sparse pollution on large beaches

1. These prices include transport of wastes until primary storage. The transport costs can be estimated at 6 to 10 FF/m^3

mended if it cannot reach the beaches without detrimental effects to dune or other areas sensitive to heavy equipment.

- Availability—In case of a large spill reaching the coast, large quantities of equipment are needed.
- Cost—An expensive and effective but specific type of equipment cannot be purchased in a quantity large enough to play an important role during the cleanup without unduly increasing the cost.
- Compatibility with handling and disposal of wastes—When landfilling is possible, it is advisable to collect the oil with a certain amount of sand to avoid oil migration; but when landfilling is difficult, further treatment is required, and more selective methods are advisable.

This list of criteria is not exhaustive; moreover, it may not clearly rank the criteria, but productivity, selectivity, impact on ecosystems and availability certainly are the most important ones.

The traditional methods. Skimming and pumping the oil on the surface of the water are recommended but will not be considered here.

Manual pick up is performed with shovels, rakes or scrapers depending on the form of oil deposit, for example, fresh, weathered, or agglomerated on seaweeds. Bulk wastes are handled further by front loaders and trucks or put in bags. Manual cleanup is a very versatile method and the only one possible in inaccessible areas. It is a very selective method but not a productive one. After cleanup by manual means, environmental recovery can be quick due to the quality of the cleanup and the minimum disturbance caused by human activity.

Depending on local conditions, different kinds of public works devices can be used. On large beaches they are very productive but, except on thick and continuous oil deposits, the selectivity is low. Large numbers of such equipment are available, but their use is expensive. Furthermore, this heavy equipment greatly disturbs the beach equilibrium and ecosystem because it buries the oil in the sand and removes blocks. For all these reasons, its use should be limited.

This quick analysis points out the lack of equipment which would be productive, selective, and relatively non-destructive to the beach environment.

Selectivity and production

The best way to achieve high productivity is to mechanize the cleanup with use of light, selective equipment. This choice limits its field of use to accessible and large beaches, but this restriction seems acceptable because of their tourist value.

There are two ways to achieve high selectivity with mechanized cleanup. The first is to collect the upper layer (about 10 centimeters) of sand and to sift the oil from it. The second is to pick up the oil directly from the sand by adhering to a specific material.

Both have been investigated, first by looking for existing equipment which could recover oil and second by designing and developing a new piece of light equipment.

The screening option. Screening is a very usual process in industry, especially for sorting gravels in quarries. It is based on granular size differences. The main limitation in its use for beach cleaning is that the oil can be separated from the sand only if it is consistent enough (tar balls) or agglomerated on litter or seaweeds.

Collecting, then selecting. In this case, oil and sand are picked up by scrapers and loaders, put in stockpiles right on top of the beach and sifted with a quarry sieve unit. This method requires much public works equipment and trucks suited for driving on beaches. The continuity of flat beaches is a favorable condition for this intensive work.

Sifting when collecting. The approach chosen by CEDRE has been to look for equipment which could simultaneously collect and sift. This type of equipment commonly is used in the summer to retrieve seaweed and litter on sandy beaches.

Almost all are built according to agricultural technology, but they can be separated into three main classes: (1) simple rakes hauled by an agricultural tractor, (2) equipment in which collecting and sifting are performed by a series of teeth or chains which turn around axles and rake the upper layer of sand (Figure 1), and (3) equipment which scrapes the upper layer of sand with a blade and sifts the sand on a vibrating mesh or a revolving belt (Figure 2).

The ability of these systems to collect oil was tested by field trials in which rows of artificial pollution were created by spreading chocolate mousse or chocolate mousse agglomerated with rubber powder or leather pieces. Three devices were tested, one from class 2 and two from class 3 (Figure 3).

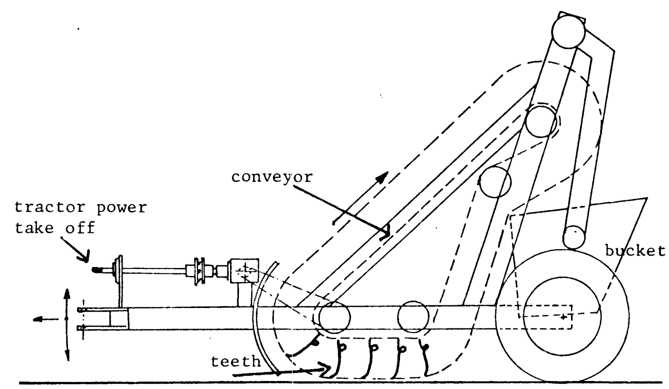

Figure 1. Class 2 beach cleaning equipment, working principle

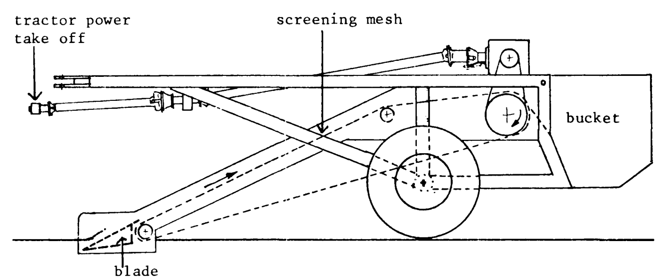

Figure 2. Class 3 beach cleaning equipment, working principle

Figure 3. Field tests of beach cleaning equipment

The trials showed that the class 2 equipment cleaned well but picked up too much sand. One class 3 device had good results both on cleaning and screening, but the other broke the agglomerates too finely by too strong a sifting action.

Because of their good performance, two types of these cleaners were used during the *Tanio* cleanup to collect agglomerated oil and weathered tar balls. The field results were even better than during the trials due to a better consistency of the real pollution.

The advantages of this equipment are:

- Trailed by an agricultural tractor, it can clean between 2,000 and 10,000 square meters per hour with a team of only two men.
- It has a fairly good selectivity (10 to 20 percent oil in the wastes).
- It collects oil in a 10 cm thick layer of sand.
- Wastes are stored in a bucket and can be put directly in a truck, when the bucket is full.

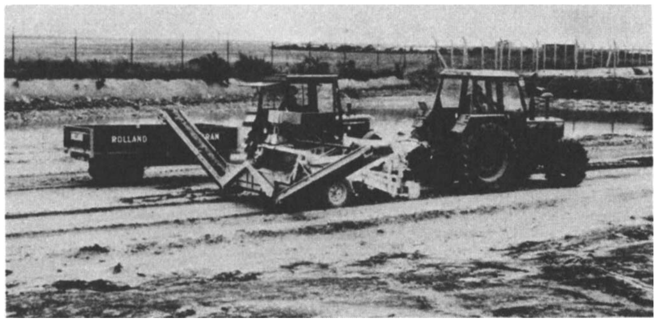

Figure 4. Field test of ROLBA kit on CEDRE's experimental beach

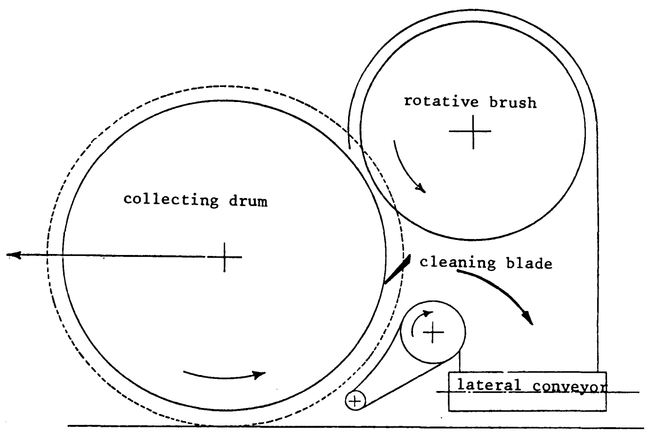

Figure 5. Working principle of the selective drum

- It is light and does not damage the beach environment.
- It is available in tourist areas.

It has a few drawbacks:

- Tar balls formed by oil mixing with the sand during the sifting process tend to fall back onto beaches when the oil is not well agglomerated. During the field tests, the reasons for this phenomenon were analyzed for each type of equipment. Although difficult to avoid in the class 2 equipment, the problem could be ameliorated on the class 3 machine.
- The presence of a bucket to store the wastes leads to a discontinuous operation. Its small capacity is adapted to litter recovery but not to cleanup of a large amount of oily residue.

In class 3, the ROLBA UMA 150 is the machine most widely used on French coasts. It was decided, therefore, to study necessary modifications with the help of the manufacturer. These modifications were in the form of a kit easily adaptable to the existing machines.

The efficiency is improved by a new design of the front collecting blade. The flow of sand toward the screening belt is improved by vibrating the blade; furthermore, this reduces the power needed to operate the beach cleaner. The ability to screen agglomerated oil is improved by a better flow of the wastes on the front blade and the immediate transfer of the wastes by a conveyor to a trailer or a dump truck. This avoids accumulation of wastes at the rear of the screening belt, and increases the speed of the operation.

The kit is powered by a hydraulic pump driven by the tractor power take-off. The front blade is vibrated by an eccentric axle actuated by a hydraulic motor which can be disengaged at will. Wastes are transferred through a distributing rear belt to two conveyors, one on the right side, the other on the left; the slope of these conveyors is adjustable. The conveyor belts are entirely retractable for driving on roads. This kit has been successfully tested on weathered bunker fuel in CEDRE's experimental facilities (Figure 4).

The selective cleanup option. Collecting the oil selectively with an oleophilic material is well known. Many skimmers are built on this principle to recover a thin layer of oil from the sea surface. On land, the problem is different. The oil often is thick and the viscous layers can be more or less agglomerated with sand or litter.

No single existing type of agricultural or industrial equipment was suitable, so it was decided to study a specific type of equipment on the condition that the machine be light, not too expensive, and easy to use and maintain. The guiding principle of this study has been to line a rotating drum with a collecting material which could be cleaned after each revolution of the drum.

Choice of collecting materials. Field tests were organized to screen different materials which could pick up the oil. It was decided not to rely on absorption properties, which on weathered oil may be very poor, but only on physical adherence or wedging. The first selection was done on a practical level, with three types of materials: (1) materials with perpendicular fibers, like artificial greens or textile carpets, on which the oil sticks; (2) metallic materials such as wire netting, with holes through which the oil can pour and then be retained; and (3) synthetic rubber material with protuberances in which the oil wedges.

Altogether, 23 materials were tested on three types of pollution, including a 1 cm thick layer of chocolate mousse from the *Amoco Cadiz* spill, and the same emulsion agglomerated with rubber powder and leather bits.

Square pieces of each material were applied on these deposits under a controlled pressure. A series of applications and cleaning was performed to study changes in results due to oiling and damping of the material. These tests showed that picking up agglomerated oil was difficult due to the hardness of the deposit and the lack of adherence.

The chocolate mousse generally was well recovered by the type 1 materials, but some with long hairs were difficult to clean, and once dirty collected no oil at all. Type 2 materials were inefficient as soon as water was on top of the chocolate mousse. Type 3 materials needed a constant radius application to take up the oil.

As a result of these experiments, three materials were chosen for further evaluation: a flat textile carpet, a wire netting, and a rubber material with protuberances.

The selective drum. The collecting materials first were placed on a very simple frame, a cylinder one meter long with a 0.9 m diameter. This cylinder is cleaned by a blade or a comb, depending on the collecting material, and the waste is stored in a rear bucket (Figure 5).

This equipment was tested during the *Tanio* cleanup and appeared to be recovering correctly, but seaweed caught between the drum and the cleaning blades blocked the rotation of the drum.

It then was decided to motorize the drum hydraulically, improve the cleaning system, and replace the small waste bucket with a high capacity conveyor. The conveyor would transfer the wastes directly to a wagon driven separately alongside the drum.

The resulting equipment consists of two units—a side unit which carries the drum and a central one with the conveyor belt. The two units are articulated to ensure a permanent adaptation to the beach profile and can be disassembled for transport.

Three types of collecting drums can be used for picking up a wide range of oily deposits: for thick deposits (a few inches), a roller with protuberances cleaned by a rotative brush; for a one-inch deposit,

Figure 6. Selective drum on CEDRE's experimental beach

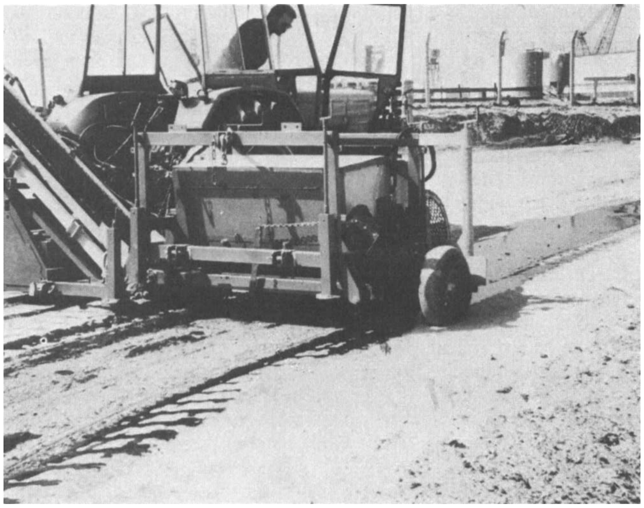

Figure 7. Selective drum on CEDRE's experimental beach

wire netting and an internal scraper; and for thin layers, a textile carpet cleaned by an outside scraper.

The selective drum is connected to the agricultural tractor by its three-point rear suspension link. The position of the drum can be controlled by a hydraulic jack fitting the upper point. Minimal power of the tractor is 40 horsepower (a four-wheel drive tractor is not necessary but recommended for better operation on sand). A double hydraulic circuit is compulsory. The selective drum is actuated by a hydraulic power pump driven by the power take-off of the tractor. Hydraulic lines are fitted with quick couplings.

The selective drum has been tested under several conditions to assess its efficiency and evaluate its performances. Most of these tests have been done in CEDRE's experimental beach in Brest (Figure 6).

Different types of oil were used—bunker fuel, chocolate mousse, and bunker fuel agglomerated with sand—and different forms and thicknesses of deposits—1 to 5 mm and 1 to 2 cm thick continuous slicks, or patches spread on sand. The prototype also was tested during a real cleanup on fresh bunker fuel containing seaweed and pebbles. The performances were judged by pictures of the oil on the experimental rows before and after the roller action (Figure 7).

The oil content of the wastes was measured. In these conditions, the selective drum picked up as much as 80 percent of the oil in a very thick layer in one or two passes. The working speed of the equipment is two to four kilometers per hour, allowing cleanup of an average of 2,000 square meters per hour. The wastes contain up to 50 percent oil with an average of 30 percent in volume.

Comparison

A distinct balance of the positive and negative values of each cleanup method (Table 2) is not possible due to the different weight given each parameter in the final rating. Except for manual labor, however, a selective cleanup method seems more appealing than use of heavy equipment in most situations.

Conclusions

Several kinds of selective cleanup equipment have been tested and are operational. Of course, they are not completely versatile and need trained operators, but they perform well on accessible beaches and diminish the quantity of wastes to be disposed of.

For these reasons, French authorities have decided to purchase some of them for the national stockpile and to develop a complete waste treatment process adapted to their performance.

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Table 2. Comparison of beach cleaning methods

Method	Productivity	Selectivity	Versatility	Access	Availability	Cost	Impact Results
Manual labor	–	+	++	++	++	–	+
Public works equipment	++	–	+	–	++	–	–
Beach cleaner	++	++	–	–	++	++	+
Selective drum	++	++	–	–	–	++	++