Management of oily waste water pollution generated by land based sources

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Abstract

Coastal water is liable to recurrent oil spills from land based oil production, industrial and power generation sites. Technologies for source control are always preferable from the financial and environmental standpoints. However, accidental release of oily wastes mandates immediate interventions via state-of-the art technologies. An integrated set of source and accidental oily waste management is recommended in almost all coastal zones with priority dedicated to those locations nearby touristic sites such as Red Sea and Mediterranean Sea. This paper sets practical criteria for identification, selection and prioritization of oily waste water management via source control and/or accidental release. Identification schemes include; mechanical/physical separation, dissolved air floatation, advanced membrane separation and chemical interventions. The latter scheme capitalizes on the latest advances in flocculation and dispersing technologies. Moreover, financial indicators including capital, operating and unit costs have been developed for specific treatment loads.

Key words: oily waste water, treatment, membrane, separation

Introduction

Oil pollution has become one of the most serious global environmental issues during the last 30 years; it exists in different forms and is generated by various sources. Oily wastewater originates from a variety of industrial sources such as oil refinery, petroleum industries, steel manufacturing, metal processing, vehicle repairs, floor and car washing, lubrication processes and other accidental spills or accidents [1-3]. Oil that is found in contaminated water can be classified into five categories: Free oil, which is oil that rises rapidly to the surface under calm conditions. Mechanically emulsified oil; are find droplets ranging in size from microns to a few millimeters electrostatically stabilized without influence of surfactants. Chemically stabilized emulsions: surface active agents provide enhanced stability due to interaction at the oil/water interface. Chemically emulsified or dissolved oil: this includes finely divided oil droplets (5 micron diameter), benzene and phenols [4-8].

Treatment and recovery options for oily wastewater fall into four main processes; mechanical, chemical, physical and biological treatment processes. The selection of the most appropriate technology or combination of technologies for oil-containing wastewater treatment is dependent on a number of factors including wastewater flow rate, composition and loading patterns, site characteristics, operation and treatment capabilities, and treatment objectives [6, 9]. Mechanical methods are mostly based on gravity separation as the most common primary treatment of oily wastewater since it removes the free oil component. Conventional mechanical separators e.g. skimmer, decanters, enhanced gravity separation technologies such as hydro-cyclones and centrifuges have been commonly utilized in the last decade [3, 9].

Upstream dispersed oil could be removed via mechanical coalescing and chemical coagulation. Flocculation systems have been employed to modify the oil droplet upstream of the primary treatment. This method is normally suitable for low-concentration oil emulsions. Filtration process can be carried out by various types of filter media ranging from coarse granular to fine particles as it has been reported that the removal efficiency reaches 90% reduction of influent oil concentrations. Microfiltration and other membrane systems have been reported as an effective separation technology for dissolved and emulsified oil [10-13]. In addition the membrane process is also used as an additional water treatment stage for upgrading plants as a polishing stage. Adsorption processes are commonly used for tertiary treatment to remove trace amounts of oil and emulsifier. Among the adsorbents used are silica base material, organic polymer, bentonite, activated carbon etc. [14].

Biological processes have also mainly employed to remove soluble organic matters remaining after physico-chemical treatment. Biological treatment is only effective for highly diluted oily wastewater since oil components are adsorbed on microorganisms faster than they can be metabolized [15-17].

The removal of oil might sometimes require a combination of methods. The Dissolved Air Flotation (DAF) process, for example, includes two different stages: (a) the chemical stage, which consists of emulsion breaking and creation of solid aggregates (coagulation and flocculation) by chemical addition, and (b) the physical stage, which separates the aggregates from the liquid phase using very fine air bubbles released under pressure. This process has been reported to achieve oil removal of 80% to 90% [6, 8, and 18]. Galil and Wolf also reported the removal efficiency of dissolved organic matter at 40% using the DAF process [19].

The paper focuses on identification of process milestones with relevant techno-economic indicators. Quantitative aspects of compensation for accidental oil pollution are briefly discussed.

Methodology

Identification of process milestones and relevant techno-economic indicators comprises the following:

- Review and analysis of reported data to come up with short cut selection logic.
- Development of a process choice matrix based on reported comparative performance.

- Development of an empirical formula for estimation of relevant treatment process/compensation cost based on the size.
- Financial comparison among treatment schemes.

Results and Discussion

Available technologies for treating oily wastewater have been reviewed with emphasis on the wastewater characteristics and evaluated according to the oil load/type to be removed as in table 1. Regardless of the industry, the evaluation and selection of oily wastewater treatment technologies, typically follows a logical series of steps that help to meet the goal of minimizing the environmental effect of wastewater produced as well as the oil contained in this water.

Table 1, Technologies for oily wastewater treatment [6, 8, 10-22]

Technology	**Type of oil to be treated**	**Type of treatment**	**Efficiency**
Physiochemical			
oil trap	free oil	primary	66%-99%
skimmers	free oil	primary	66%-99%
API	free oil	secondary	66%-99%
centrifugation	free oil	secondary	66%-99%
flotation	free oil	secondary	66%-99%
DAF	free oil/dispersed oil	tertiary	60%-80%
IAF	free oil/dispersed oil	tertiary	65%-80%
Coalescence	free and emulsified oil	secondary	30%-70%
Chemical			
Coagulation	dispersed oil	secondary	70%-90%
dispersion	dispersed oil	secondary	70%-90%
oxidation	dispersed oil	secondary	15%-30%
electro-chemical	dispersed oil	secondary/tertiary	13%
Physical			
Gravity separation	free oil	primary	66%-99%
Membrane	dissolved and emulsified oil	tertiary	75%-90%
adsorption	emulsified oil	secondary	66%-99%
Biological			

MBR	dissolved and stabilized emulsions	tertiary	94%
up flow anaerobic sludge blanket	dissolved and stabilized emulsions	tertiary	74%
biological aerated filter	dissolved and stabilized emulsions	tertiary	94%

DAF: dissolved air flotation, API: American Petroleum Institute, IAF: Induced air flotation MBR: membrane biological reactor

A typical treatment system for oily wastewater comprises pretreatment, primary, secondary, tertiary and final polishing stages as shown in Figure 1. Based on the selection criteria listed above as well as the state-of-the-art technologies available for each treatment stage, a logical framework diagram has been constructed as depicted in Figure 2. In this diagram, the level of treatment, being primary, secondary or tertiary, is selected based on the type of oil. Furthermore, the treatment technologies are selected based on the footprint

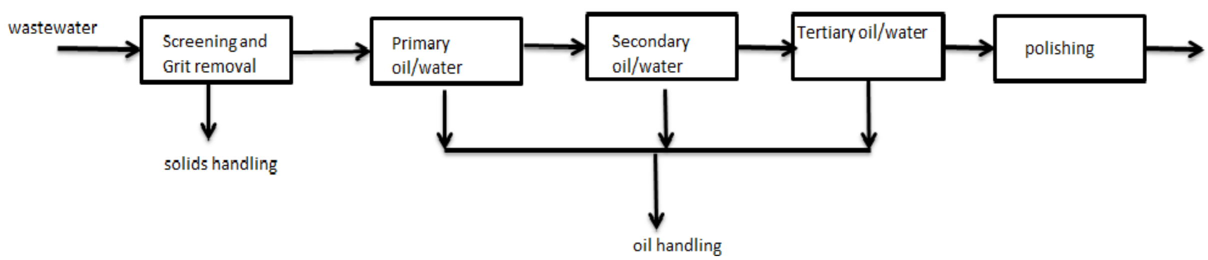

Figure 1, typical oily wastewater treatment system

Development of an empirical formula for estimation of relevant treatment process/compensation cost based on the size of pollution (in tons of oil) is presented in equation 1. The developed equation is based on reported data as well as case studies presented in literature [23-32].

cost/ton = - 685.47 ln(size in ton) + 10993.15……………………………….(1)

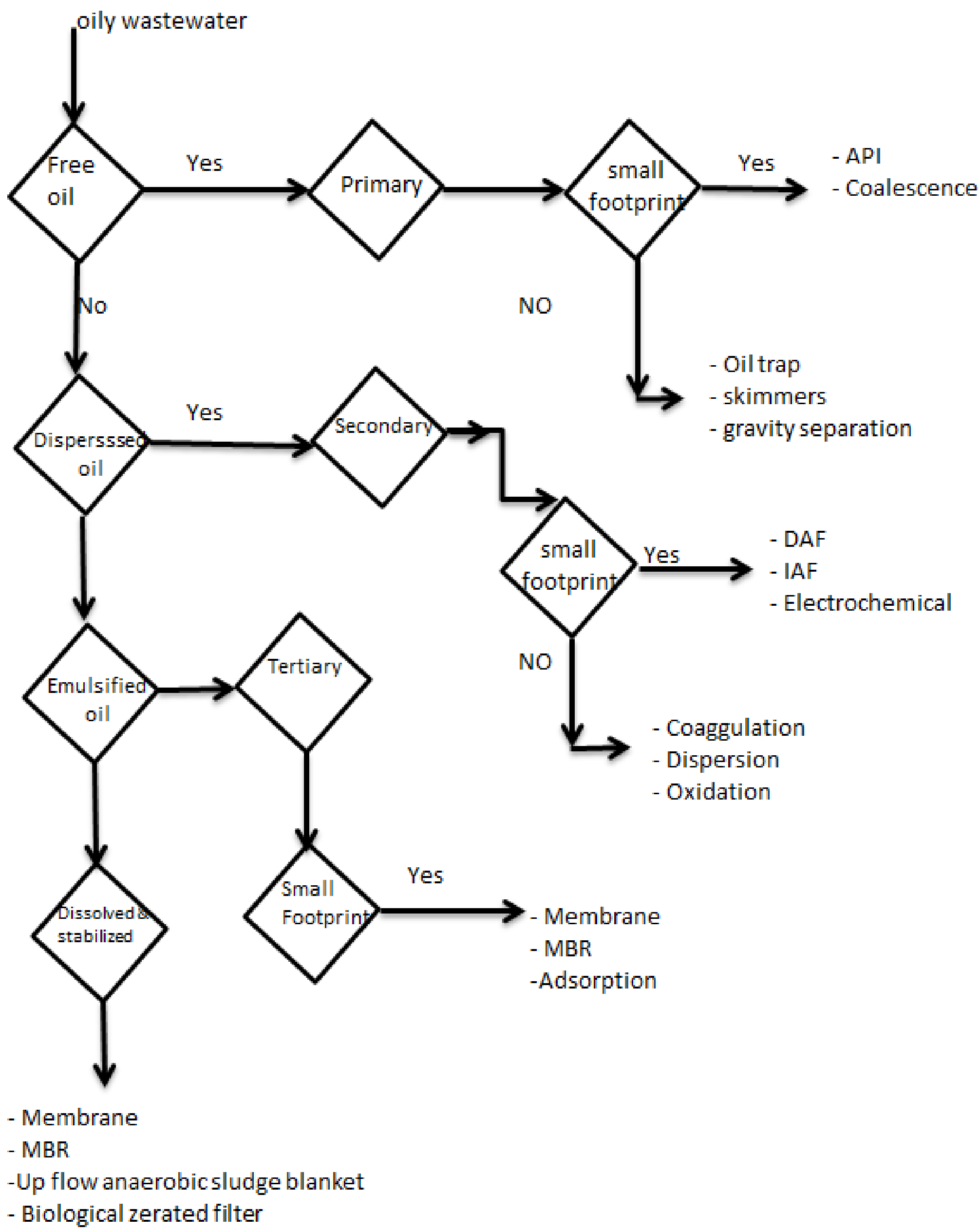

Figure 2, Logic frame diagram for oily wastewater treatment technologies

According to the logic frame diagram, three case studies have been evaluated for oily wastewater treatment.

Case 1:

Feed water containing oil and suspended solids from wastewater. Influent conditions are typically 300 to 10,000 ppm oil and TSS (free oil). The adopted treatment scheme according to the selection criteria and logic diagram comprises screening and API and/or oil trap for small footprint required.

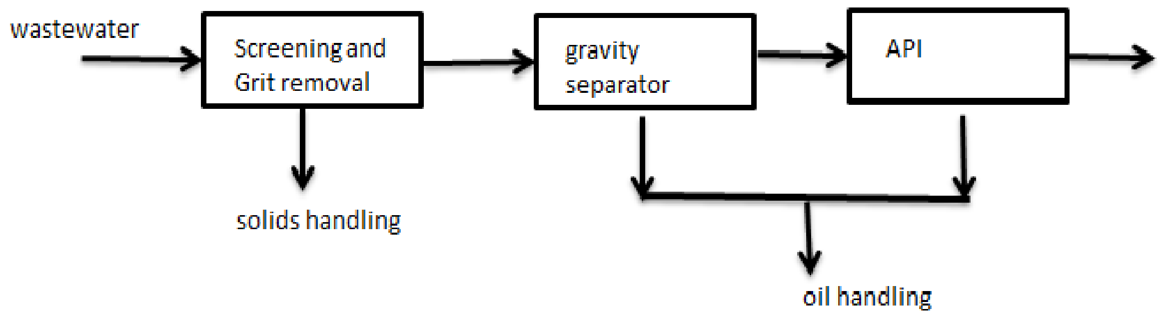

Figure 3, Treatment process diagram for Case 1

Case 2

Feed water containing oil and suspended solids from wastewater. Influent conditions are typically 150-30 ppm oil (free oil, dispersed and emulsified oil). The adopted treatment scheme according to the selection criteria and logic diagram comprises screening, API and/or oil trap, DAF, and membrane treatment.

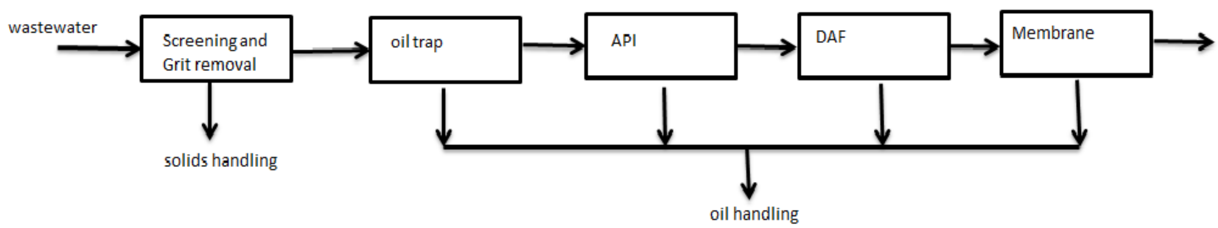

Figure 4, Treatment process diagram for Case 2

Case 3

Feed water mainly contains 60% dispersed and 35% emulsified oil. The adopted treatment scheme according to the selection criteria and logic diagram comprises screening, DAF/coalescence, and membrane treatment.

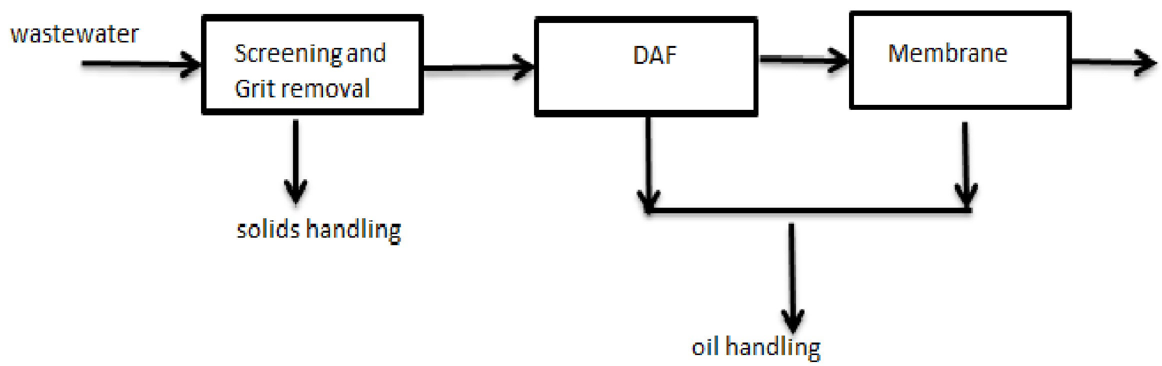

Figure 5, Treatment process diagram for case 3

The updated cost using ENR-CCI cost index 2014 [ ] of the selected schemes is presented in figure 6. The capital cost estimated for the three proposed schemes are $518430, 10071937, and 41576562 respectively. The estimated O&M cost are $ 91722, 5390529, and 26887567 per year respectively.

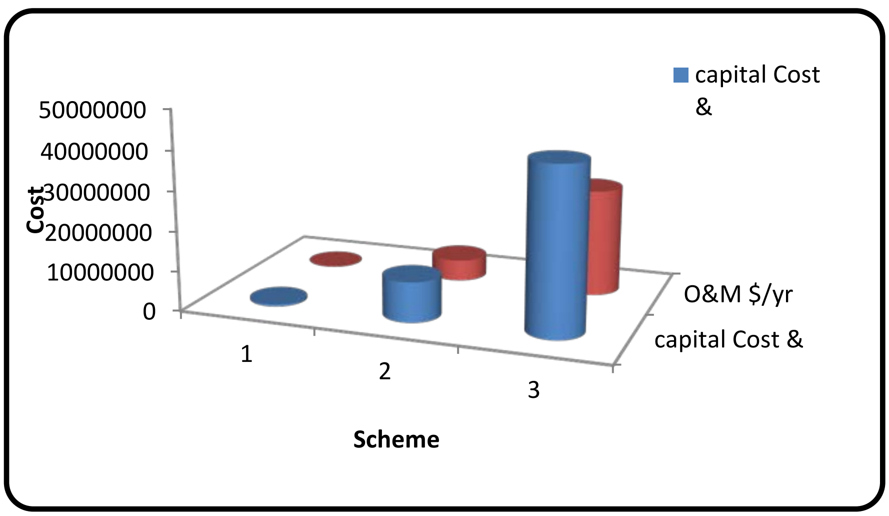

Figure 6, Selected schemes cost

Conclusion

Decision support on the selection of appropriate process for the treatment of oily wastewater/oil spills have been developed based on combination/screening and analysis of reported data. Performance analysis leads to the development of a simple choice matrix that enables rapid identification of a suitable treatment process out of different screened options. The choice matrix is supported by tailored decision support logic to refine the selection process further. The financial aspects/compensation based on the size of pollution has been also discussed. Finally; three proposed schemes/interventions have been identified and evaluated.

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