CLEANING AGENTS FOR OILED WILDLIFE

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ABSTRACT

Attempts to save oiled wildlife cannot be successful unless appropriate treatment is given. One of the more critical areas of rehabilitation is the selection and correct use of a suitable cleaning agent. The advantages and limitations of detergents and solvents are discussed with respect to the types of wildlife affected, the types of oil involved, and the available equipment and facilities. Seven commercial detergents out of 22 tested are ranked in order of their effectiveness in removing eight specific types of oil. Optimal concentrations and available toxicity data are also given. Solvents that have been successfully used are listed along with other solvents that appear promising on the basis of their composition and physical parameters. Further evaluations of cleaning agents and additional basic research are still needed.

INTRODUCTION

Selecting a cleaning agent is one of the major decisions to be made when rehabilitating oiled wildlife. The following should prove helpful to those faced with such a problem.

A few terms need defining within the scope of this paper. A detergent is any chemical or mixture of chemicals which has the ability to cleanse when in aqueous solution. Alkali salts of naturally occurring fats, otherwise known as soaps, are examples of detergents. Surface-active agents, surfactants, are chemicals which have the ability to lower the surface and interfacial tensions of aqueous solutions. This ability usually results in a capability to cleanse so that most surfactants may be classified as detergents. For many applications, the best cleansing is accomplished by mixtures of surfactants with other chemicals which by themselves are not surface active.[5] These mixtures also fit the definition of detergents.

The term "solvent" is reserved for liquid hydrocarbon formulations with a flash point below 85°C. Mineral oil (British equivalent: medicinal paraffin) is any minimally-toxic liquid hydrocarbon solvent with a flash point of 125°C or higher. For further information on hydrocarbon solvents we refer the reader to *Physical Chemistry of Petroleum Solvents* by Reynolds.[6]

Appropriate treatment

Oil mats fur or feathers and thus eliminates the trapped air that provides thermal insulation. However, it is not enough to merely remove the oil from an oil-soaked animal. The animal may be suffering from dehydration, malnutrition, internal hemorrhaging, dermatitis, central nervous system depression, or any of a number of other physiological problems.[10] Competent veterinary care is therefore necessary for the rehabilitaton of oiled wildlife. On the other hand, mammals that do not depend upon fur for thermal insulation may not require cleaning, particularly if the oil is minimally toxic.

Criteria for an ideal cleaner

1. Able to remove any oil, fresh or aged, quickly and easily
2. Leaves pelage or plumage waterproof and otherwise normal
3. Minimally toxic to both animals and people
4. Minimal hazard in storage, use, and disposal
5. Inexpensive

Regarding the first criterion, most oils are easily removed by warm solvent or mineral oil. We found solvent to be relatively poor, however, at removing a mixture of oil and bilge cleaner (a surfactant). Also, only very hot solvents are able to easily remove extremely viscous oils. Unfortunately, they would kill the animal and seriously endanger the people doing the cleaning. Detergents, when used properly, can be quite effective at removing a large variety of oils.

With respect to the second criterion, a little needs to be said regarding waterproofing in general. Feather wax is important for the waterproofing of a bird's plumage but not even warm solvent nor warm detergent will remove enough to matter.[7] Abrasion, however, can remove sufficient wax to impair waterproofing. Abrasion can occur if the plumage has sand in it or the bird scoots across an abrasive surface.

Feather wax is insufficient to confer waterproofing to feathers that are less than scrupulously clean and precisely arranged or imbricated down to the microscopic level.[1, 7] Feather imbrication becomes disturbed when the bird attempts to preen out heavy oils or grit from its plumage or when people handle birds incorrectly. The proper imbrication can be restored in most cases when the bird preens following the removal of oil.

Almost any kind of "dirt" in a bird's plumage will adversely affect waterproofing and hence thermal insulation. The most effective agent for interfering with waterproofing is detergent or a similar surface active chemical which acts as a wetting agent and lowers the surface tension of water. Detergents have been used to kill birds in Kentucky when their density became a nuisance. The detergent was sprayed onto the roosting birds by aircraft. When the birds were exposed to moisture the detergent acted as a wetting agent. The wet feathers provided little thermal insulation and the birds died of exposure. Theoretically, the birds could have survived by thoroughly rinsing themselves in clean water. Sufficient rinsing could have removed the detergent and left the plumage waterproof once again.

The following, therefore, are the possible reasons that a bird might not be waterproof after cleaning: (a) feather wax partially removed by abrasion; (b) feathers insufficiently clean; (c) microscopic imbrication disturbed; (d) detergent residues remaining. The pelage of a mammal does not have the advantage of regular imbrication but is otherwise similar to plumage with respect to waterproofing. Abrasion, "dirt," and detergent residues decrease the waterproof status of fur.

Solvent and detergent do not appear to affect the waterproofing of animals, assuming that the detergent is thoroughly rinsed out.[1] If mineral oil is used, it must also be thoroughly removed to restore waterproofing.

The third criterion for an ideal cleaner is that it be minimally toxic to animals and personnel. All solvents and detergents are toxic to some degree. If they defat the skin they can cause a dermatitis to which some animals and people are more susceptible than others. Detergents cause conjunctival irritation if splashed in the eyes. Solvents are toxic when inhaled or absorbed through the skin. Although mammals probably absorb solvent more slowly than do birds, it is likely that mammals are far slower in ridding themselves of the solvent. Our very limited experience with solvent on furred mammals suggests that it may be too toxic for use. This problem needs to be studied further. Birds, on the other hand, withstand solvent remarkably well when suitable protective procedures are employed. Birds smaller than 300 gm have a somewhat poorer survival rate when cleaned in solvent, suggesting

that a surface/volume effect may favor larger birds. Toxicities of various detergents are listed in Table 1.

The fourth criterion for a cleaner is that it be minimally hazardous in storage, use, and disposal. If accepted practices are followed for the storage and disposal of solvent, then there will be no problems of safety. The potential for danger, however, still exists, especially in the hands of the inexperienced or careless. Using solvent to clean birds can be safe, but only if proper procedures are strictly followed. The International Bird Rescue Research Center has cleaned more than 2,000 birds with solvent without incident. Detergents offer no particular problems except that slippery floors may result. This is also true with solvent or mineral oil.

The fifth criterion for an ideal cleaner is that it be inexpensive. Solvent to clean a moderately-oiled one kilogram bird may cost from $1.50 to $7.50 depending on the solvent selected and the quantity used. Detergent for the same bird may cost from $0.50 to $25.00 depending on which detergent is selected and the concentration needed to best remove the oil. Naturally it is false economy to select a less effective or more toxic cleaner merely because it is the cheaper. Inadequate cleaning will result in a longer term of captivity and a second cleaning, both of which will add to overall expense.

Theoretical considerations concerning detergent use

The cleansing ability, or detergency, of a detergent is dependent on many factors which can be classified under the following headings: (a) wetting and spreading; (b) rolling-up process; (c) emulsification; (d) solubilization; (e) foaming; (f) mixed phase formation; (g) protection against redeposition.[4,5,8] A very brief description of each of these may help in understanding the problems inherent in cleaning oiled animals with detergents.

Wetting and spreading. The detergent solution needs to spread through the fur or feathers being cleaned and wet the individual hairs or feather barbs.

Rolling-up process. The solution should be able to successfully compete with the oil for contact with the surface of the barbs or hairs. Oil, except for highly viscous oil, that is spread out along a surface will be pushed together into a ball and released from contact with the surface.[4] This is easy to observe by placing an oiled test feather into a detergent solution. Agitation and high temperatures aid in the rolling-up process.

Table 1. Data for selected liquid detergents

Product name	Amber Lux	Basic I	Conco K	Grease Relief
Manufacturer	Lever Brothers	Shaklee Products	Continental Chemical Co.	Texize Chemical Co.
Current as of	1976	1976	1976	1976
Acute oral toxicity	NA	LD_{50}: 4.2g/kg	LD_{50} rats: 0.65 g/kg (7 days)	LD_{50}: greater than 30 ml/kg
Local effects on eyes	primary irritant	corrosive	mild irritant	non-irritant
Local effects on skin	non-irritnat	corrosive	moderate irritant	non-irritant
pH	6.6	12.8	7.8	8.8 - 9.3
Surfactant type	anionic	nonionic	nonionic	anionic and nonionic
Price/liter	$0.93 - 1.11	$0.58 - 3.80	$1.29	$0.92 - 1.68

Table 1. Data for selected liquid detergents (continued)

Product name	Liquid Concentrate	Nokomis	Polycomplex A-11
Manufacturer	Bestline Products Inc.	Nokomis International Inc.	Guardian Chemical Co.
Current as of	1972	1976	1976
Acute oral toxicity	LD_{50} rats: greater than 6.4 g/kg	LD_{50}: greater than 15 g/kg	LD_{50}: 10 g/kg
Local effects on eyes	mild to moderate irritant	irritant	non-irritant
Local effects on skin	non-irritant	non-irritant	non-irritant
pH	8.3	10.4	9.5 - 9.8
Surfactant type	nonionic	nonionic and anionic	NA
Price/liter	$3.44	$0.99 - 1.56	$1.58 - 1.99

Emulsification. A considerable amount of oil can be suspended in a detergent solution if the oil is formed into droplets and surrounded by surfactant. The size of the droplets can vary from being clearly visible to the eye to microscopic. Emulsions of microscopic droplets have a cloudy appearance.[4, 5]

Solubilization. Detergents have some capability to dissolve oils and hold them in a true solution.[5, 9] Such a solution would be clear and not cloudy if an emulsion were not also present.

Foaming. Some investigators consider the formation of foam to be an important contributor to detergency but others disagree. It is possible that the formation of suds and bursting of bubbles supply advantageous mechanical action.[8]

Mixed phase formation. Surfactant is capable of penetrating the polar components of an oil, altering the physical properties of the oil.[4] Under some conditions this probably aids detergency. We have observed, however, that excessive concentrations of some detergents result in the oil becoming crystalline in appearance, noticeably more viscous, and highly resistant to subsequent attempts at removal. More will be said about concentration later.

Protection against redeposition. There is a certain tendency for oil in an emulsion to become redeposited on available surfaces. Detergents are usually formulated to minimize this tendency. The practice of washing something in two brief baths rather than one longer bath will also help to minimize redeposition.[5, 8, 9]

There are three well-defined parameters controlled by workers cleaning oiled animals with detergents. They are: (a) concentration; (b) temperature; and (c) agitation.

Concentration. For every oil type and degree of aging there is an optimum concentration of the chosen detergent. These optimal concentrations are considerably higher than concentrations recommended for most cleaning chores. Our investigations suggest that the optimal concentration in any given instance is bounded at the upper end by the formation of a sufficiently stable mixed phase of surfactant and oil to impede further cleansing. This oil-surfactant phase resists removal by any concentration of detergent in subsequent attempts at cleaning. The practical value of this is clear: if too high a concentration of detergent is used on an oiled animal the animal will become nearly impossible to clean. Table 2 presents the optimal concentrations for 7 detergents as used on 8 different fresh oils. Note that "Grease Relief" is sufficiently dilute that it is most effective when used full strength while "Polycomplex A-11" is so concentrated that a 1% solution is too strong for some kinds of oils.

After an animal has been washed for a period of time in detergent at the optimal concentration, it is then rinsed with water. The process of rinsing means that the detergent is continually becoming more dilute as rinsing progresses. In our work with feathers, it sometimes appears that very little cleansing is accomplished while the feathers are in the solution of optimal concentration but that the bulk of the cleansing occurs during the rinsing process. The high optimal concentrations may favor some processes of cleansing but not others. Removal and dispersion often occur most readily during rinsing when lower concentrations result. When evaluating detergents it is therefore important to grade the appearance of the feather after rinsing, as this best corresponds to the treatment to be received by an oiled animal.

Temperature. In the range that detergent solutions are used on live animals, higher temperatures result in more efficient cleaning. The viscosity of the oil is lowered and the kinetics of detergency are enhanced. The temperature limit is set by what becomes injurious to the animal being cleaned. Smaller animals in particular can be easily overheated. Clinical thermometers should be used to monitor the body temperatures of representative animals undergoing the cleaning process.

Agitation. Detergency is aided by the input of mechanical energy.[5, 9] When cleaning birds, however, the amount and manner of agitation must be limited to avoid mechanical disruption of feather structure. Acceptable modes of agitation include patting, gentle stroking of the plumage in the direction of the lay of the feathers, spraying with medium velocity jets of detergent solution or water, and ultrasonic cavitation. Mammals may be additionally rubbed or brushed.

Table 2. Detergents ranked in order of their cleansing ability with selected oils under experimental conditions; optimal concentrations in water by volume are listed beneath each ranking number

	Alaskan crude	Bunker C	Mineral oil	Motor oil (waste 30W)	Murban crude	Qatar crude	Residual	San Joaquin crude
Amber Lux	1 8%	1 15%	1 8%	1 8%	1 8%	2 15%	1 30%	2 50%
Basic I	3 100%	3 15%	3 100%	4 100%	2 100%	1 50%	3 100%	6 30%
Conco K	4 1%	6 4%	4 0.5%	5 2%	5 1%	3 0.5%	4 1%	4 1%
Grease Relief	7 100%	2 100%	7 100%	6 100%	6 100%	7 100%	6 100%	5 100%
Liquid Concentrate	2 100%	4 50%	2 100%	2 50%	3 100%	4 100%	2 100%	1 30%
Nokomis	5 100%	5 100%	5 100%	3 100%	7 100%	6 100%	5 100%	3 100%
Polycomplex A-11	6 1%	7 4%	6 0.5%	7 4%	4 0.5%	5 1%	7 1%	7 1%

Evaluations of selected detergents

Seventeen liquid detergents and 5 powdered detergents were screened for their effectiveness in removing oil from feathers. Two of the liquid detergents, "Zif" and "Solution 1553" were eliminated from the testing when we decided not to include solvent-detergent hybrids. Neither product appeared outstanding at the time they were eliminated, however. "Eco Plus" was eliminated when our supply was exhausted and we had trouble finding more of the product. Of the 14 remaining liquid detergents, 7 are listed alphabetically in Table 2 along with how they ranked in cleansing ability on 8 types of fresh oil. Beneath each rank number is the optimal concentration in water by volume of the detergent when used with that oil. The other 7 liquid detergents were found to be generally less effective. They were "Ajax Dishwashing Liquid," "Basic H," "Era," "Janitor In A Drum," "L.O.C.," "Lux Dishwashing Liquid," and "Woolite." Although "Shaklee's Basic I" appears in Table 2, it should not be seriously considered for cleaning live animals as it is too caustic (high pH) at the concentration where it is comparable to some other detergents.

Of the 5 powdered detergents, "Cheer" used at a concentration of 67% and "Boraxo" at 17% were moderately effective in removing oil from feathers. "All," "Co-op Low Sudsing Laundry Detergent," and "Tide" were less effective.

The following method was used to evaluate detergents. An oiled feather was dropped into 25 ml of detergent solution at 40°C in a pint jar. The lid was quickly secured and the solution was gently agitated with a uniform motion for 15 seconds. The degree of agitation was duplicated as closely as possible for each trial. The contents of the jar were then immediately dumped into a collander and gently rinsed with 40°C water. These conditions were chosen to approximate what we felt individual feathers might encounter during the cleaning of a live bird. This was fairly well substantiated by the cleaning of several live birds during our evaluation program. There are, of course, almost limitless variations possible for this kind of testing.[1, 3, 5, 8, 9]

Recommendations for using detergents

It is probable that the limiting factor in using detergent to clean large numbers of oiled animals will be the lack of hot water. A heavily-oiled one kilogram bird might easily require 40 liters of water at 45°C. Attempts to clean several hundred birds in a single day will tax all but the larger commercial hot water systems.

After the appropriate detergent concentration has been determined, the detergent solution is then carefully made up at 45°C or at a temperature shown to be less stressful to the animals being cleaned. The animal is washed first in one basin and then in a second. Hands should be protected with rubber gloves.

Rinsing is most easily accomplished with a spray nozzle on the end of a flexible hose dispensing water at 40-45°C with moderate pressure. As the animal is rinsed, it becomes less wet. At some point it is arbitrarily decided that further rinsing will yield no further benefit and the animal is dried and checked by veterinary or para-veterinary personnel.

The local sanitation department should be consulted as to whether the dirty cleaning solution may be poured down the drain.

Recommendations for using solvents

Know the flash point of any solvent you use. The higher the flash point the less the fire and explosion hazard. The flash point is the temperature at which sufficient solvent vapor will collect in a closed container of liquid solvent to support combustion. Below the flash point the ratio of solvent to air is too low for combustion.[2] One should never use a solvent at or above its flash point.

Some organic solvents are more toxic than others. Generally, aromatic hydrocarbons are more toxic than straight and branched chain hydrocarbons (aliphatics). High molecular weight aliphatics are the least toxic of the solvent constituents. The vapors of benzene, an aromatic, when inhaled can cause destruction of bone tissue.[2] Commercial organic solvents are mostly a mixture of many discrete compounds of varying toxicity. The overall toxicity of a solvent is therefore dependent on the percentage composition of each of its constituents. In practice, it is possible to find commercial solvents with aromatic hydrocarbons forming less than 1% of the product.

Table 3 lists several solvents that are acceptable for cleaning birds from the standpoint of toxicity. This is not meant to imply that these products may be used carelessly. Inhalation of the vapors from any of these solvents will have an anesthetic effect resulting in drowsiness, confusion, loss of equilibrium, and headache. A certain amount of absorption can occur through the skin and may result in symptoms similar to those resulting from inhalation. Skin contact often cause a dermatitis.

Another significant consideration in selecting a suitable solvent is the evaporation time. Until the solvent on an animal thoroughly evaporates, the animal continues to be exposed to the toxic effects of that solvent. Evaporation times are listed in Table 3. For the above reason and because of evaporative cooling, forced hot air must be used to dry an animal cleaned with solvent.

An informative, but brief and non-technical, booklet describing safe practices for using solvents is available from Exxon Corporation entitled, "Handling Petroleum Solvents."

Before cleaning, the solvent must be heated to 37-40°C for birds or 34-37°C for mammals to prevent chilling. The higher temperatures favor the solvent's cleaning effectiveness but increases the generation of solvent vapor and, hence, the problems of inhalation toxicity and fire danger. Electric heaters for 55 gallon drums are suitable if they are equipped with thermostat sensors that are immersed in the solvent. All electrical equipment should be properly grounded to prevent sparks. Working around solvent requires suitable respirators, gown, gloves, and goggles. The work area must be well-ventilated and kept free from flames, burning cigarettes, or other hazards.

The actual cleaning of oiled birds with solvent is in most respects similar to cleaning with detergents. Warm solvent is dispensed into basins and the bird is washed for half a minute or so before proceeding to a second basin of warm solvent. A third basin may be necessary in some instances. The bird is then rinsed with jets of warm solvent dispensed under moderate pressure to remove the last traces of oil.

Rapid and thorough drying is mandatory. The International Bird Rescue Research Center uses a dryer of our own design that delivers a high volume of fresh air at 43°C upwards through a plastic floor grate. Nevertheless, birds suffer a residual toxicosis that renders them "drunk" for three to six hours. They are put in padded pens for this period.

The dirty solvent is suitable for re-refining.

General recommendations

Be prepared. Know where cleaning agents and ancillary equipment can be acquired. Be certain that your sources are just as able to supply your on a holiday weekend night as at any other time. It is best to have an adequate stockpile of necessary items and cleaners so that rehabilitation of oiled animals can begin without delay. Conduct training workshops so that key personnel are thoroughly familiar with the cleaning process, husbandry, safety and health measures, and general organization of an oiled wildlife rehabilitation effort. Locate a facility with adequate space, hot water, electricity, light, ventilation, and heating.

Test the cleaners. If birds are involved, pluck several oiled body feathers from a living bird or carcass to use in testing detergent solutions. If no birds are involved but mammals are, testing may be conducted with pieces of white wool cloth uniformly soiled with oil collected from the oil slick. Alternatively, the wool cloth may be soiled by wiping oiled mammals. Keep all experimental conditions constant except the brand and concentration of the detergents. Follow the test procedures outlined in the section "Evaluation of Selected Detergents." By comparing the samples after they are dry, it is possible to narrow down the choice of detergent and concentration. The final choice can be made after testing with more samples or with whole carcasses. The optimal detergent solution for one day might be different for the following day due to aging of the oil.

It is not uncommon for birds to be coated with oil approaching the viscosity of roofing tar, the high viscosity being the result of aging. Such oil is not easily removed by detergents but warm solvent or mineral oil is effective, though slow. Solvent can be removed from the birds by forced-air drying or by detergent; mineral oil can be removed by detergent or solvent. Recall that we do not recommend that solvent be used on mammals. The process of using warm mineral oil followed by detergent is particularly

Table 3. Hydrocarbon solvents

Product name	Isopar G	Isopar H	Naphthol Spirits 663	Odorless Gulfsol	Solvent 70	Solvent 71
Manufacturer	Exxon	Exxon	Union	Gulf	Shell	Shell
Current as of	1975	1975	1975	1969	1970	1970
Flash point °C	41	53	39	51	40	51
Flash point °F	105	127	102	123	104	123
Evaporation rate (time in seconds to 100%)	2200	5100	NA	NA	3067	9460
Composition (volume %)						
Paraffins	99.9	99.9	61		98.2	97
Naphthenes			39	100	0.9	3
Olefins		0.03				
Aromatics	0.05	0.05	1		0.9	
Price/liter	$ 0.37	NA	$ 0.23	NA	$ 0.20	NA

attractive since it requires less protective equipment and poses less of a fire hazard. Whether this will work in a full scale oiled animal rehabilitation incident is yet to be seen.

Another way to remove a very viscous oil is to use a warm surfactant with a low HLB (hydrophilic-lipophilic balance) number followed by cleaning with a normal cleansing detergent. Such highly lipophilic surfactants act in much the same manner as solvents. Mineral oil, however, may work about as well and cost less.

The final recommendation is to carefully divide up the responsibilities of operating an oiled animal rehabilitation effort. It is simply not possible for any one person to orchestrate such an endeavor with its many varied facets.

CONCLUSION

There has been no room for dogma in the technology of oiled animal rehabilitation. Those that insisted on the superiority of any one cleaning agent have been humbled by experience. Both detergent and solvent have been highly successful in certain instances. Mineral oil is a special case since it too must be removed in order for the animal to be released within an acceptably short period of time. The greatest drawbacks to the use of detergent are its inability to effectively remove some oils and its need for prodigious quantities of hot water. The drawbacks to the use of solvent are its toxicity and flammability. We hope further progress will be made toward reducing these disadvantages and improving the cleaning of oiled wildlife.

More evaluations of detergents need to be made. There are literally hundreds of detergent products available, but only 22 were examined by us for their potential as cleaning agents for oiled wildlife. Solvent-detergent hybrids were excluded from our study because they appear to offer the worst qualities of both detergent and solvent, i.e. the requirement for great quantities of hot water and the problem of toxicity. Perhaps we were wrong in excluding those products. The only way for us to learn is to continue researching. Any advances will contribute to survival of wildlife affected by oil spills and probably result in reduced labor and costs.

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