Comparative Study of Conventional and Compact Detergents

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ABSTRACT: Experimental work has been carried out on conventional and compact detergent formulations. Comparative study has focused not only on the package size but also on the type of builder contained in the finished product. The detergency as a function of dosage and some parameters concerning the environmental impact of each category of formulation also have been evaluated. Soiled (with carbon black/olive oil) cotton and polyester/cotton fabrics have been used to determine the detergency (% soil removal). Considering the overall results obtained, it can be stated that compact tripolyphosphate-built detergents impose the lowest chemical load upon the environment for the same detergency performance.
JAOCS 73, 27–30 (1996).

KEY WORDS: Builder, detergency, powder detergents, sodium tripolyphosphates (STPP), zeolites.

The current controversy regarding the use of detergent formulations, built with sodium tripolyphosphates (STPP) or other builders (1–4), as well as the benefits of either conventional or compact packaging (4,5), has encouraged us to perform a comparative study of a series of commercial detergents that are used for washing textiles. Eutrophication, which is a complex problem, was not examined here. The main aims of the study were the following: (i) experimental determination of chemical parameters that are related to the aquatic environment; (ii) experimental determination of detergency for each detergent category; and (iii) evaluation of the environmental impact at equivalent detergency performance.

EXPERIMENTAL PROCEDURES

Detergent samples. Detergent powders were purchased in supermarkets in Spain. Among nine detergents tested, five were conventional or standard (≅4-kg package): three of these contained STPP as the builder, and two contained other builders. The other four detergents were compact or concentrated (≅2-kg package), two of which were built with STPP and two that contained another type of builder.

Preliminary treatment of samples and analytical determinations. All samples were subjected to a preliminary treatment to reproduce a typical European textile-washing process. A suspension of a 10-g sample in 1L of deionized water was heated for 30 min under agitation in a 60°C thermostated waterbath. After allowing the resulting preparation to cool, the following parameters were measured: (i) total suspended solids (TSS): A homogenized aliquot was filtered through a glass microfiber filter (GF/C; Whatman International Ltd., Maidstone, England), and the residue retained on the filter was dried to a constant weight at 103–105°C (6); (ii) dissolved organic carbon (DOC): A 1:100 diluted aliquot was subjected, after membrane filtration (0.45 μm pore size), to decarbonation by stirring the sample previously acidified with HCl. DOC was determined by the combustion infrared method (7) in a TOCOR-2 (Maihak, Hamburg, Germany); (iii) chemical oxygen demand (COD): A 1:20 diluted aliquot of the supernatant, resulting from the preliminary treatment, was analyzed for COD by potassium dichromate oxidation (8); and (iv) biodegradability: The "Modified OECD Screening Test" was used to determine the biodegradability of the samples (9). Biodegradation is reported as the percentage of DOC removed within 28 d. The starting DOC concentration was 20 mg/L. All the analytical determinations were performed in duplicate.

Washing tests. Washing tests were carried out at 50°C in an automatic washing machine (Otsein DL-680 BB; MAYC S.A. Vergara, Guipuzcoa, Spain). The detergent concentrations tested were 5, 10, and 15 g/L. The water total hardness (Ca + Mg) was 200 mg/L as $CaCO_3$, and the load/volume ratio was 3.5 kg towel fabric per 20 L. The standard fabrics used were soiled (with carbon black/olive oil) cotton fabric (EMPA 101; EMPA, St. Gallen, Switzerland), soiled polyester/cotton (65:35) fabric (EMPA 104), and unsoiled cotton fabric (EMPA 221). For the washing tests, four 12 × 12 cm swatches of each standard fabric were sewed onto the towel fabric. The swatches were dried 24 h at room temperature.

The reflectance of the test swatches was measured before and after washing by using a blue filter in a Elrepho photometer (Carl Zeiss, Oberkochen, Germany). Reflectance measurements were made at four points for each standard fabric swatch. Soil removal, as detergency, was calculated according to the following equation:

$$\% \text{ soil removal} = 100\,(R_f - R_i)/(R_r - R_i) \qquad [1]$$

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where R_f, R_i, and R_r are, respectively, the reflectance of the soiled fabric after washing (*f*), the soiled fabric before washing (*i*), and the unsoiled fabric before washing (*r*).

RESULTS AND DISCUSSION

In Tables 1 and 2, information on individual and average compositions for the tested detergents are given. The diverse detergents are gathered in four categories, based on the package type and the builder used: *P*-based conventional, *P*-free conventional, *P*-based compact, and *P*-free compact. The results obtained for the chemical parameters and biodegradability for the four detergent categories are shown in Table 3.

It is clearly shown that *P*-based formulations (both conventional and compact) contain, not only much less TSS (due to the insolubility of zeolites), but have also lower COD and

TABLE 1
Individual Compositions of Tested Detergents (%)

	Conventional					Compact			
	P-Based			*P*-Free		*P*-Based		*P*-Free	
Component	*A* 4 kg	*B* 4 kg	*C* 4 kg	*D* 4 kg	*E* 4 kg	*F* 1.7 kg	*G* 2.2 kg	*H* 2.2 kg	*I* 2.2 kg
Water	12.0	11.0	10.0	9.0	12.0	20.0	5.0	9.0	11.0
Surfactants	15.0	14.0	13.0	12.0	18.0	13.0	13.0	20.0	20.0
STPP[a]	23.0	21.0	20.0	—	—	50.0	27.0	—	—
Zeolites	—	—	—	19.0	30.0	—	—	22.0	27.5
Sodium carbonate	11.0	8.5	4.0	10.0	16.0	2.0	20.0	25.0	20.0
Sodium silicate, $R = 2$	4.5	5.7	5.7	2.0	2.0	7.0	5.0	3.5	2.0
Polymers	3.5	2.5	3.2	4.0	3.5	2.2	—	3.2	5.0
Sodium perborate • 4 H_2O	12.0	13.0	14.0	14.0	—	—	12.0	—	—
Sodium perborate • 1 H_2O	—	—	—	—	—	—	—	13.0	9.0
Perborate activator	Yes	Yes	Yes	Yes	—	—	Yes	Yes	Yes
Enzymes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sodium sulfate	18.0	22.0	30.0	25.0	18.0	3.0	10.0	3.5	2.0
Density (g/cm^3)	0.60	0.60	0.50	0.57	0.58	0.55	0.70	0.70	0.65

[a]Sodium tripolyphosphates.

TABLE 2
Average Compositions of Tested Detergents (%)

	Conventional		Compact	
Component	*P*-Based	*P*-Free	*P*-Based	*P*-Free
Surfactants	14.0	15.0	13.0	20.0
STPP[a]	21.3	0.0	38.5	0.0
Zeolites	0.0	24.5	0.0	24.7
Na_2CO_3	7.8	13.0	11.0	22.5
Polymers	3.1	3.7	1.1	4.1

[a]Sodium tripolyphosphates.

TABLE 3
Mean Values of Chemical Parameters and Biodegradability for Each Detergent Category

	Conventional		Compact	
Parameters	*P*-Based	*P*-Free	*P*-Based	*P*-Free
TSS[a] (mg/g)	19	290	22	274
COD[b] (mg O_2/g)	397	536	351	519
DOC[c] (mg/g)	116	148	110	174
% Biodegradability (after 28 d)	51	45	53	53

[a]Total suspended solids.
[b]Chemical oxygen demand.
[c]Dissolved organic carbon.

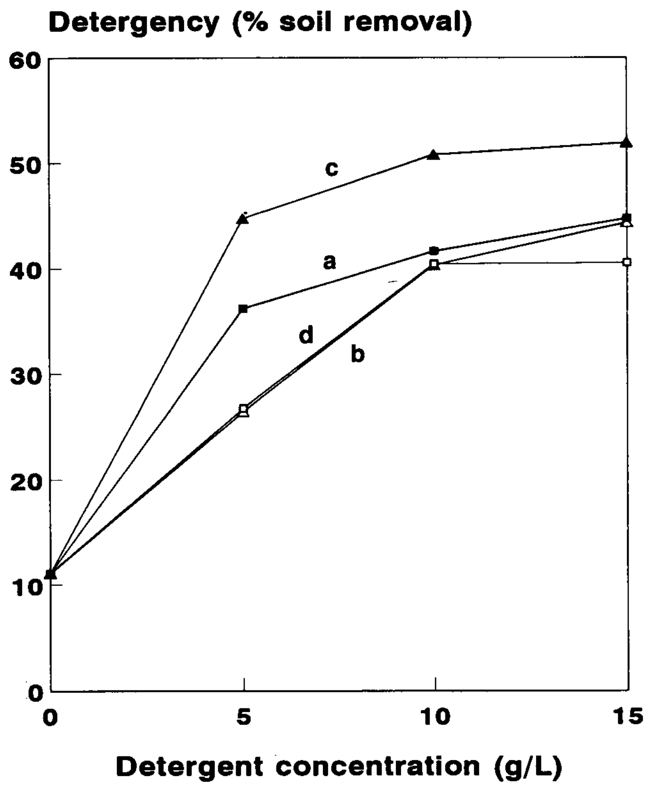

FIG. 1. Detergency on soiled cotton fabric for each detergent category at the detergent concentrations tested: a(■), *P*-based conventional; b (□) *P*-free conventional; c (▲), *P*-based compact, and d, (△), *P*-free compact.

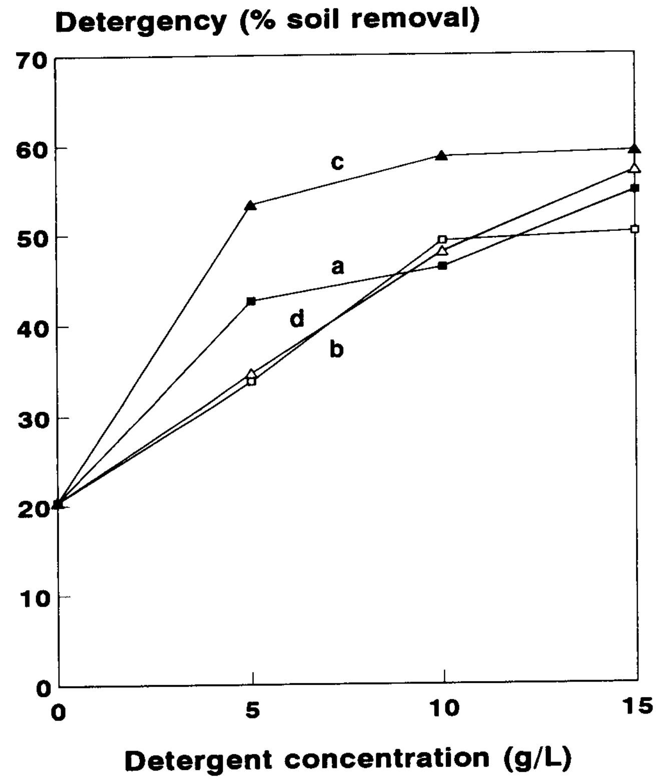

FIG. 2. Detergency on soiled polyester/cotton fabric for each detergent category at the detergent concentrations tested: a (■), *P*-based conventional; b (□), *P*-free conventional, c (▲), *P*-based compact, and d (△) *P*-free compact.

DOC than do *P*-free formulations. The results on biodegradability are similar for the four detergent categories, as expected, because all detergents contain basically the same organic ingredients (alkylbenzene sulfonates + ethoxylated fatty alcohols). The detergency results (% soil removal) for each detergent category are plotted in Figures 1 and 2 for the two fabrics tested as a function of the resulting detergent concentration in the bath.

For *P*-free formulations, the change from conventional to compact packaging does not affect detergency. On the contrary, when using a *P*-based compact detergent instead of a *P*-based conventional detergent, better detergency performance is achieved. Also, it seems obvious that, with *P*-based compacts, the same soil removal is achieved with a lower amount of detergent in the washing bath. This implies, logically, a smaller discharge of detergent to the aquatic environment.

In Figures 1 and 2, it is shown that the common maximum soil removal of the four detergent categories is 40% on cotton fabric and 48% on polyester/cotton fabric. Considering a detergency on cotton fabric of 40%, the calculated detergent dose is 8.8, 10, 4.4, and 10 g/L for *P*-based conventional, *P*-free conventional, *P*-based compact, and *P*-free compact detergents, respectively. In the same way, the calculated detergent dose is 11.9, 10, 4.2, and 10.6 g/L, respectively, for detergency on polyester/cotton fabric of 48%.

In Tables 4 and 5, the results of chemical loading to the environment, considering an equal detergency performance, are calculated for a typical wash (20 L). It can be seen that detergent load, surfactant load, COD, DOC and, above all, TSS are substantially smaller for *P*-based than for *P*-free detergents, specially for *P*-based compacts. In other words, the use of compact detergents, built with STPP, implies a lower environmental impact than the other three types of detergents, in terms of both a reduced generation of sludge residues and a reduced organic load in sewage works.

TABLE 4
Chemical Loading of the Tested Detergents to the Environment for a Detergency on Cotton Fabric of 40%[a]

	Conventional		Compact	
Parameters	*P*-Based	*P*-Free	*P*-Based	*P*-Free
Detergent load (g)	176.0	200.0	88.0	200.0
Surfactant load (g)	24.6	30.0	11.5	40.0
COD (g)	69.9	107.2	30.9	103.8
DOC (g)	20.4	29.6	9.7	34.8
DOC remaining after 28 days[b] (g)	10.0	16.3	4.6	16.4
TSS (g)	3.4	58.0	1.9	54.8

[a]See Table 3 for abbreviations.
[b]According to biodegrability test.

TABLE 5
Chemical Loading of the Tested Detergents to the Environment for a Detergency on Polyester/Cotton Fabric of 48%[a]

	Conventional		Compact	
Parameters	*P*-Based	*P*-Free	*P*-Based	*P*-Free
Detergent load (g)	238.0	200.0	84.0	212.0
Surfactant load (g)	33.3	30.0	10.9	42.4
COD (g)	94.5	107.2	29.5	110.0
DOC (g)	27.6	29.6	9.2	36.9
DOC remaining after 28 days[b] (g)	13.5	16.3	4.3	17.3
TSS (g)	4.5	58.0	1.8	58.1

[a]Abbreviations as in Figure 3.
[b]According to biodegrability test.

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[Received February 20, 1995; accepted October 30, 1995]