17. Wilson, A.L. (Carbide and Carbon Corp.), U.S. Patent No. 2,267,965 (1941).
18. Smith, F.D., and W.M. Linfield, JAOCS 55:741 (1978).
19. Chakrabarti, P.M. (GAF Corp.), German Patent No. 2,559,698 (1977).
20. Chakrabarti, P.M. (GAF Corp.), U.S. Patent No. 3,941,817 (1976).
21. Hein, H., H.J. Jaroschek and W. Melloh, Fette Seifen Anstrich. 80(11):448 (1978).
22. Critchfield, F.E., and J.B. Johnson, Anal. Chem. 29(8):1174 (1957).
23. Phillips, A.P., and R. Baltzly, J. Am. Chem. Soc. 69:200 (1947).
24. Van Tamelen, E.E., Ibid. 73:5773 (1951).
25. Wechsler, J.R., T.G. Baker, G.T. Battaglini and F.L. Skradski (Stepan Chemical), U.S. Patent No. 4,189,593 (1980).

[Received June, 1982]

Nonionic Surfactants in Municipal Sewage in Israel

U. ZOLLER and **R. ROMANO**, Division of Chemical Studies, Haifa University—Oranim,
P.O. Kiryat Tivon, 36910, Israel

ABSTRACT

Nonionic surfactants are a significant factor in the municipal sewages profile, which, in turn, affects the efficiency of sewage-treatment processes and determines the possibility of sewage-water reuse. Hard (nonbiodegradable), nonionic surfactants are the most commonly used nonionics in Israel, which probably has no parallel in other western industrial countries. In view of the increased share of nonionic surfactants at the expense of anionic surfactants, a worldwide trend, municipal sewages in Israel were expected to contain increasing amounts of nonionic surfactants, unless the ratio between the biodegradable and nonbiodegradable nonionics used was significantly changed. In vivo determinations of nonionic surfactants in representative municipal sewage systems in Israel, applying a modified SDA-cobalt thiocyanate (CTAS) procedure and calibration curves (prepared under in vitro conditions), established typical concentrations of nonionic surfactants in municipal sewage in the northern part of Israel to be in the range of 3-4 mg/L. Under the particular local situation, a calibration curve derived from a mixture of nonylphenol ethoxylates (NP_{8-14}), having a slope of 0.165 absorbance units/mg of nonionic, can be reliably used to determine the content of nonionic surfactant of municipal sewage effluents. A correction factor based on the extent of nonionic recovery should be applied to ensure accuracy. All of the results obtained agree with other relevant studies and worldwide trends. The concentration of nonionic surfactants in municipal sewage in Israel appears to be decreasing. The results of the study, selected aspects involved with the determination procedure under in vivo conditions and issues relevant to the problem of nonionic detergents in municipal sewage, are discussed. The contribution of the study toward the improvement of water quality, thus increasing its potential for reuse in Israel (and elsewhere), is emphasized.

INTRODUCTION

Synthetic detergents, of which a substantial portion are nonionic surfactants (1), constitute a significant factor in the municipal sewage profile (2-4) in developed and developing countries all over the world. This factor, in turn, determines the possibility of sewage-water reuse after appropriate purification and recovery processes (5).

In Israel, which is a model of efficient water use (6), the reuse of recycled and reclaimed water is probably the most effective response to the scarcity of water resources in the quantity and quality required on the one hand, and the overexploitation of existing resources on the other. The reuse and exploitation of treated municipal sewage is no exception. The types, quantities and properties of the detergents present in such effluents constitute a determining factor as far as their removal is concerned (7). However, the reuse of water on a large scale opens a Pandora's box with respect to the environmental consequences involved (8).

THE PROBLEM AND SCOPE

The resistance to biological degradation is characteristic for a substantial portion of the existing types of nonionic surfactants (9). In addition to causing serious foaming problems, they interfere with sewage treatment processes, as do other types of synthetic detergents (4). Thus, the nonbiodegradable, branched-chain alcohol and alkylphenol ethoxylates are responsible for the various aspects of short- and long-term environmental problems involved in their use, i.e., economic-technological, biological-ecological and aesthetic-psychological. Combining the above information with the assertion that complex energy and environmental issues will dominate the future growth and apportionment of the surfactant business (10) enables one to appreciate both the scope and impact of the issue of nonionic surfactants in municipal sewage.

Indeed, surfactants are, at present, a £7.1 billion market with a growth rate of 2.7% a year in the US and Canada alone (11). Nonionic surfactants, which account for ca. 30% of the total production (12), are made up of ca. 200 commercially produced nonionics, of which alkoxylated linear alcohols not only make up the largest portion of this type (13), but also represent the fastest growing nonionic surfactant class.

The passage of governmental legislation in the western industrial countries, with respect to environmental constraints, has made criteria for large-volume surfactants such as alcohol ethoxylates (AE), in which the alkyl group is predominately linear, and alkylphenol ethoxylates (APE), in which the alkyl group, in most cases, is highly branched, more stringent than the foaming reduction required of the alkybenzenes sulfonates in the 1960's. Consequently, much research has been carried out, both in industry and academia, to assess the biodegradability and environmental safety of AE and APE. On the other hand, the global energy crisis stimulated the use of lower temperature, effective, soluble liquid detergents which, in turn, favor the more soluble and hardness-insensitive nonionic surfactants. As a result, we are now witnessing a significant shift in the relative share of nonionic detergents in the detergent market, at the expense of the so far dominant linear anionic detergents.

As a consequence of the above trends, municipal sewage is expected to contain increasing concentrations of nonionics surfactants, unless the ratio between the biodegradable and nonbiodegradable nonionics used is changed significantly in favor of the former. In reality, this means more ethoxylated linear alcohols (AE) at the expense of alkylphenol ethoxylates (APE).

Unfortunately, in Israel, where all the ethoxylated-based nonionic surfactants are imported from the US and Europe, the nonbiodegradable APE dominate the nonionic market. The growth of the consumption of nonionic surfactants in Israel (first introduced in the country in 1964) is shown in Table I.

The most commonly used APE in Israel are the branched-

TABLE I

Consumption of Nonionic Surfactants[a] in Israel[b]

Year	Tons
1973	1085
1974	2100
1975	2300
1978	2750
1980	3200[c]

[a] Mostly ethoxylated alcohols and alkylphenols, the ratio between which is highly in favor of the latter.

[b] Population size: 3.5 million.

[c] Estimation; no solid data are yet available.

chain nonylphenols (Fig. 1a) and dinonylphenols (Fig. 1c) with HLB of 12.5-14, both considered to be very hard surfactants, i.e., highly resistant to biodegradation because of their branched alkyl chain and aromatic ring (7,14). The former is being used in liquid and powder formulations, whereas the latter is used almost exclusively in low-foam, heavy-duty laundry powder formulations (15). Some ethoxylated (branched-chain) octylphenols (Fig. 1b) are also used. The soft (biodegradable) AE-$C_n H_{2n+1}$-O(CH_2-$CH_2O)_mH$ are used either in liquid preparations (including shampoo formulations) or in special formulations aimed at the textile industry.

Evidently, most of the hard nonionic surfactants, as well as other detergents used in household products, find their way to municipal sewage, with all the implications that this involves.

Water Reuse in Israel

Since Israel's natural water resources have almost reached the limit of practical exploitation, effluents of municipalities—after secondary treatment—are reused in agriculture. The common way is to hold the effluents in open reservoirs and to use them during the summer, primarily for cotton irrigation (ca. 90% of the total amount).

Today, 57 × 10^6 m^3/yr effluents are used for agricultural purposes in Israel. Within 2 years, more than 140 × 10^6 m^3/yr will be used (16). This quantity is ca. 56% of the sewage in Israel (67% of the total volume of sewage collected by sewers). The reuse of this quantity of reclaimed sewage effluents is expected to replace ca. 30% of the total amount of water used today for agricultural irrigation.

Legislation in Israel banned the production and use of alkylbenzene sulfonates (DDBS) based on branched-chains, effective April, 1975. The desirable level of MBAS in water was set at 0.2 mg/L, the maximum permissible limit being 1.0 mg/L. This, however, refers to drinking water, and is concerned with anionic surfactants only. No limiting standards for nonionic surfactants in drinking water exist, nor do any official requirements concerning the tolerable level of surfactants (either anionic or nonionic) available. This is probably caused, at least in part, by the lack of data concerning the current concentrations of nonionic detergents in municipal effluents and influents on a national scale. Secondary effluents in Israel contain detergents within the range of 4-18 mg/L (17). The efficiency of removing both hard nonionic and anionic detergents from sewage influents in biological treatment hardly approaches the 30% limit (4). Nonionic surfactants, in addition to causing serious foaming problems, interfere with sewage treatment processes, as do other types of nonbiodegradable synthetic surfactants. Nonionic surfactants constitute a potential hazard to agricultural crops (18).

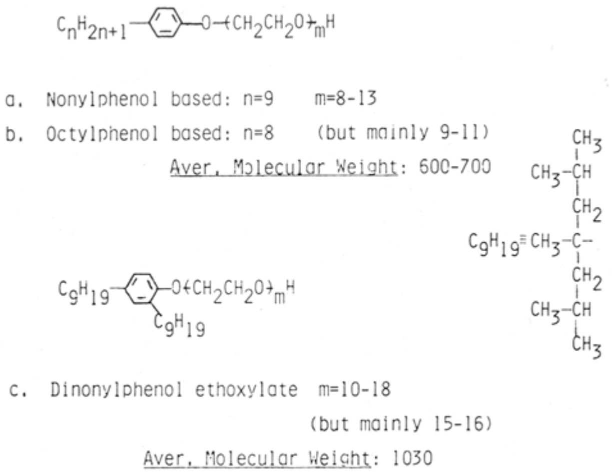


FIG. 1. Alkylphenol ethoxylates commonly used in Israel.

Consequently, the short- and long-term technoenvironmental problems involved in the presence of nonionic surfactants (particularly the nonbiodegradable types) in municipal sewage for reuse are apparent. Clearly, the reliable determination of the current concentrations of nonionic surfactants in influents of municipal sewage all over Israel is the first step of any action to be taken in the future, as far as the reuse of waste water is concerned.

Determination of Nonionics in Sewage

Any attempt to cope with the problem of the presence of nonionic surfactants in municipal sewage requires the determination of their concentration under in vivo, actual field conditions. Unfortunately, no extensive monitoring of sewage effluents has been reported for nonionic surfactants, primarily because specific analytical methods for differentiating between AE and APE and determining nonionics in the presence of a complex mixture of other detergents present in sewage have been unavailable (5,9).

The major problem in determining nonionic surfactants in sewage is 2-fold. First, the multivariant system one has to deal with is complex, particularly in view of the simultaneous presence of different types of nonionics as well as other types of detergents, i.e., anionics (linear alkylbenzene sulfonates, alcohol sulfates, ethoxylated alcohol and alkylphenol sulfates, alkyl sulfates, α-olefin sulfonates, soaps and some other types of detergent ingredients). The conditions in the system are uncontrollable and constantly changing (i.e., relative concentrations of the various components, concentration types and physical forms of insolubles, rate of flow, extent of homogeneity and so on).

This means that the available analytical methods and techniques for the determination of nonionic surfactants under controlled laboratory conditions (in vitro) should be substantially modified and appropriately applied under the particular local field conditions. That is, a special set of calibration curves should be established for each analyzed sewage influent or effluent under the particular set of local constraints.

Several analytical methods for the determination of nonionic surfactants under in vitro conditions are available. The main ones are the cobalt thiocyanate method (CTAS) (19,20), the Wickbold method using the Dragendorff reagent (DAS) (21), the thin layer chromatography (TLC) or gas chromatography (GC) method (22), and the ultraviolet (UV) method (23). Some other techniques and variations are also available. Of all the above, the CTAS method has been adopted by the Analytical Subcommittee of the Chemical and Environmental Research Committee of the Soap and Detergent Association in the US for determining nonionic surfactants in biodegradation and environmental studies (24). Thus, an analytical method and procedure, to be referred to as the SDA procedure, has been developed by this committee in which a foaming procedure for concentrating the surfactants, and an ion-exchange step for its isolation, are followed by its final determination via the colorimetric response of a cobalt thiocyanate-nonionic surfactant complex, as illustrated in Scheme 1.

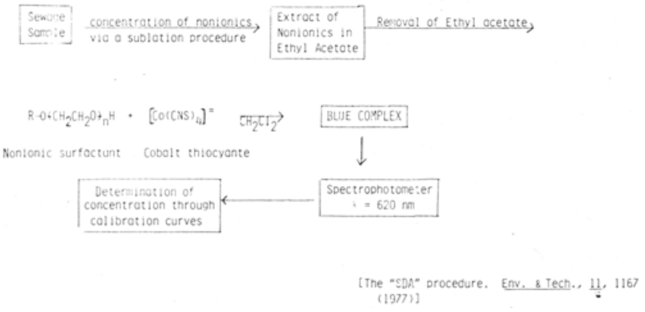
By using either the CTAS or DAS methods, 2 important matters should be kept in mind: first, the presence of anionic detergents in the final analyzed sample (after all the required procedure manipulations) may substantially affect the results (25) and hence distort the real situation. Consequently, an appropriate correction factor should be introduced. Second, these methods may provide information about the primary biodegradation of the nonionic surfactants but provide no idea about either the environmentally acceptable biodegradation or the ultimate biodegradation (26) of the nonionic surfactants originally present in the sewage being analyzed.

Keeping all the above in mind, and in view of a previous estimate of 5-15 mg/L of nonionic surfactants in sewage treatment plants in 1975 in Israel (4), we have undertaken a study of nonionic surfactants in municipal sewage in Israel. The primary objective of our project was to adapt, develop, modify and simplify existing methods for nonionic surfactant determinations. The procedures will be applied for the in vivo determination of concentrations of contemporary nonionics in typical municipal sewage effluents in Israel, which contain both biodegradable and nonbiodegradable anionic and nonionic detergents simultaneously.

Our results concerning the adaptation and modification of available analytical procedures have been published elsewhere (5). Our preliminary progress report concerning the application of the SDA method to our specific local conditions, as well as a discussion of some relevant aspects, will follow. Within our on-going research program, we are currently working not only on the determination of the present characteristic concentrations of nonionic surfactants in typical (representative) municipal sewage, but also on monitoring the ratio between biodegradable and nonbiodegradable nonionics in the inspected sewage.

EXPERIMENTAL PROCEDURES, MATERIALS AND METHODOLOGY

A modified SDA procedure (24) has been used for the initial concentration-extraction and the final determination of nonionic surfactants in the preliminary simulation runs (which used tap water), in the preparation of the calibration curves and in the final actual sewage samples. Thus, an ion-exchange step—for the separation of the anionic from the nonionic surfactants (following the sublation)—was not included in our procedure. Instead, several calibration curves of absorbance vs concentration of nonionic surfactants were prepared in the presence of an anionic surfactant (LABS) in different ratios between the two. In a low ratio of anionic/nonionic (1:1) and a total concentration of up to ca. 4 mg/L of surfactants, anionic surfactants do not interfere with the determination. With increasing ratios (anionic/nonionic > 2:1) and higher total concentrations, the anionic surfactants do interfere (25). In addition, a weighted calibration curve was used for the determination (see NP mix, Figure 3). The raw sewage samples were used as they were for the determination, without prefiltering or any other pretreatment.



[The "SDA" procedure. Env. & Tech., 11, 1167 (1977)]

SCHEME 1. Determination of nonionic surfactants in sewage samples via the cobalt thiocyanate method. [The SDA Procedure, Env. & Tech. 11:1167 (1977).]

The absorbance of the final solution of the cobalt thiocyanate-nonionic surfactant complex vs CH_2Cl_2 was measured at 620 nm in a Gilford spectrophotometer (Model 25).

Because most of the nonionic surfactants used in Israel are of the branched-chain (essentially nonbiodegradable), APE type, only commercial samples of this class were used in both the adaptation-simulation stage and for the preparation of the calibration curves.

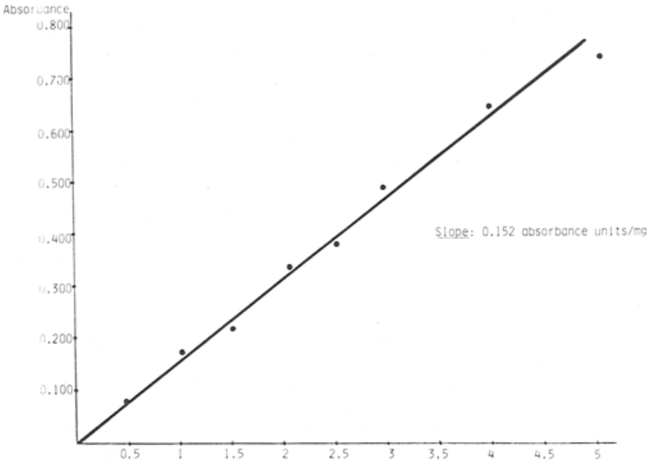


FIG. 2. Calibration curve for ethoxylated nonylphenol containing 10 mol E.O/mol (NP_{10}).

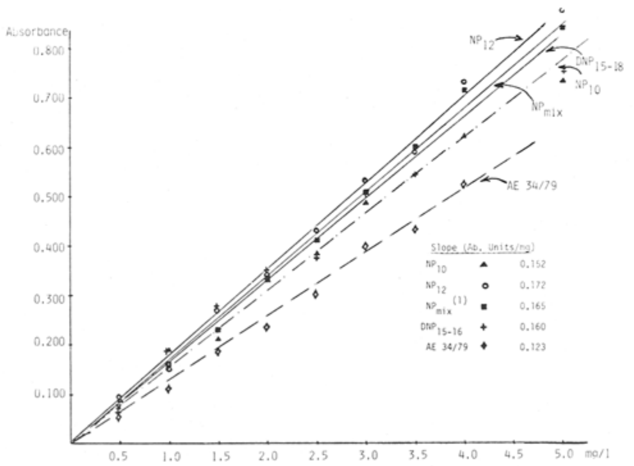


FIG. 3. Calibration curves of the hard nonyl- and dinonylphenol series.

(1)A mixture consists of NP_8, NP_{10}, NP_{12} and NP_{14} (25% each).

Thus, samples of the most commonly used nonylphenol ethoxylates (products of Huls, West Germany or GAF, US) containing 8, 10, 12 or 14 mol of ethylene oxide/mol of nonylphenyl (i.e., C_9H_{19}-C_6H_4-$O(CH_2CH_2O)_{8-14}H$; NP_8 – NP_{14}), or mixtures thereof, have been used in the study. The dominant dinonylphenol ethoxylate in the Israeli market (a product of Berol, Sweden), containing an average of 15-16 mol of ethylene oxide/1 mol of dinonylphenol (i.e., $(C_9H_{19})_2$-C_6H_3-$O(CH_2CH_2O)_{15-16}H$; DNP_{15-16}), has also been included.

NP_{10} has been used as the standard nonionic surfactant (OECD test material) (27). Following the optimization of the foaming-extraction, complexation-absorbance determination procedure, our experimental methodology can be summarized as follows:

Phase 1. Preparation of calibration curves for either the individual, commonly used nonyl- and dinonylphenol ethoxylates (NP_{8-14} and DNP_{15-16}) or a specially prepared representative mixture.

Phase 2. Determination of the extent of nonionics recovery in the sublation procedure.

Phase 3. Preparation of a summative, averaged-weighted and factorized calibration curve, to be used for the final nonionic determinations in municipal sewage.

Phase 4. Determination of known added nonionic surfactants to sewage samples.

Phase 5. Determination of the concentrations of the nonionic surfactants present in 3 representative, typical municipal effluents in the northern part of Israel.

RESULTS AND DISCUSSION

The calibration curve derived from the standard reference is shown in Figure 2. Calibration curves derived from NP_{12} and DNP_{15-16} are plotted in Figure 3. In addition, the calibration curves of the reference material, NP_{10} (Fig. 2), as well as the calibration curve derived from an equimolar mixture of 4 nonylphenol ethoxylates (i.e., NP_8, NP_{10}, NP_{12} and NP_{14}, 25% each), are also given. The calibration curve for a typical linear alcohol ethoxylate (Marlipal 34/79, Huls) was also prepared and is shown on the same figure for the sake of delineation.

Two important results are apparent from the plotted curves. First, all the curves of the nonylphenol and dinonylphenol series have very similar slopes in the range of 0.152-0.172 absorbance units/mg (for NP_{10} and NP_{12}, respectively). They essentially coincide with one another. Second, the calibration curve of the representative mixture (equimolar quantities of 4 different nonylphenol ethoxylates-NP_{mix}) also follows the same pattern (as one would expect), giving a slope of 0.165 absorbance units/mg (+0.013 and −0.007 absorbance units/mg, respectively, off the NP_{10} and NP_{12} slopes). This means that this NP_{mix} calibration curve can be used successfully and reliably for the actual determination of total nonionic surfactants concentrations in real sewage samples. Furthermore, the slope of 0.165 for NP_{mix} is only ca. 2.5% different from the slope of the DNP_{15-16} calibration curve. DNP_{15-16} was, until recently, not only the most popular nonionic surfactant used in Israel (primarily in low-foam, heavy-duty ternary detergent-based laundry powders (15)), but probably is also the hardest detergent present in Israel's municipal sewage (4). Consequently, its contribution to the content of nonionic surfactant in municipal sewage is substantial. Interestingly, the slope of the calibration curve of the representative of the AE series (i.e., Marlipal 34/79) is substantially different.

Our value of 0.123 absorbance units/mg is essentially the same as the value obtained by the SDA committee for the slope of their curve with the addition of alkyl ethoxylated alcohol (C_{12}-C_{18}), with an average ethoxylate number of 7 units, to environmental samples (24). One practical conclusion might be that if both AE and APE types of nonionic are present in an analyzed sewage (or other environmental samples), a calibration curve with a sope in the range of 0.120-0.170 absorbance units/mg can be used. The appropriate value for the slope can be established according to the relative ratio of the different types of nonionic surfactants suspected (or known) to be present in the analyzed samples. A word of caution is appropriate here: the presence of substantial amounts of anionic surfactants and other potentially interfering substances should never be underestimated, or the results one obtains may be incorrect.

The extent of recovery of added APE nonionic surfactants into aqueous solutions has been established for all the nonionics studied, using the sublation technique (7,14,21). This constitutes a vital integral step in the procedure for the determination of nonionic surfactants in sewage samples. Typical results are summarized in Table II below for NP_6 and NP_{mix}, respectively.

Thus, the extent of added nonionic surfactant recovery from aqueous solutions is shown to be the expected range of 90% ± 10% (for 2 sublations). This extent of recovery (with 4 sublations) was established by the SDA committee (24). The actual percentage of recovery to be established, using the actual sewage samples analyzed, should be taken into consideration to obtain a good estimate of the real nonionics content and the result obtained from the calibration curve should be corrected accordingly. The appropriate factor, in most cases, will fall between 1.0-1.25 (based on 90% ± 10% recovery).

Because the calibration curve derived from the NP_{mix} (Fig. 3) appeared to be appropriate and reliable for use in in vivo nonionics determinations in municipal sewage effluents, we moved on to phases 4 and 5 of the project.

TABLE II

Recovery of Added Nonylphenol Ethoxylates – NP_{10} and NP_{mix} – to Aqueous Solutions via the Sublation Process

NP_{10} added (mg)	Absorbance	NP_{10} recovered[a] (mg)	Recovery (%)	NP_{mix} added (mg)	Absorbance	NP recovered[a] (mg)	Recovery (%)
0.0	0.002	0.0	–	0.000	0.000	0.0	–
1.0	0.155	1.18	118.0	1.70	0.246	1.54	90.0
2.0	0.310	1.96	98.5	2.57	0.465	2.77	108.0
3.0	0.445	2.82	94.4				
4.0	0.620	3.90	97.6	5.15	0.730	4.32	83.9
5.0	0.750	4.80	95.5	5.50	0.827	4.84	88.0
6.0	0.935	5.77	96.1	8.25	1.305	7.68	93.1
Average[b]	→	100		Average	→	92.6	

[a] Determined through the CTAS method and the prepared calibration curves.

[b] Found by the SDA Committee to be 90% ± 10%.

Determination of the concentrations of the nonionic surfactant in 3 different sewage effluents in the northern part of Israel has been carried out. These represent 3 different types of municipal sewage. The first, Oranim (O) represents a small homogeneous community where most of the nonionics in the sewage originate in household detergent formulations for general cleaning and dishwashing. The second, Technion pilot plant, which is connected to the municipal sewage of Neve Shaanan (NS), represents a typical municipal sewage of a medium-size town. The third is Haifa Municipal Sewage Treatment Plan (HMSTP), which represents municipal sewage systems of big cities in Israel, into which substantial amounts of industrial sewage are also drained. In the HMSTP case, the presence of substantial amounts of crude oil (originating from nearby refineries) makes the determination of the content of nonionic surfactant of this sewage rather difficult.

The recovery results in these 3 sewage systems, using NP_{10} as the added nonionic surfactant, are given in Table III. The overrecovery of added nonionic surfactants in the HMSTP case may be caused by the high content of crude oils, which causes turbidity in the sewage samples analyzed. This turbidity is the cause of difficulties in both the sublation step and the determination step. Nonetheless, factors of 1.09 (100:91.1), 1.06 (100:94.3) and 0.91 (100:110) for O, NS and HMSTP have been used to correct the concentrations of nonionic surfactants in these 3 municipal sewages obtained by using the NP_{mix} calibration curve.

The determined concentrations of nonionic surfactants in the raw sewages of the 3 representative systems are given in Table IV.

The relatively small differences between the results in each sewage influent should not be surprising, since fluctuations in the contents and the relative ratio of the various components in typical municipal sewage streams are to be expected. However, the average concentration in each case correlates reasonably well with the particular nature of the analyzed sewage.

Finally, delineating the results of this study with some comparable available data is rather interesting. These results are shown in Table V.

Based on the above information, as well as on other available resources, the concentrations of nonionic surfactants in municipal sewage are decreasing. This trend might be surprising in view of the increasing share of nonionic, surface-active agents in the detergents market. However, the appreciable increase in the production and use of the degradable straight-chain alcohol ethoxylates on the one hand, and the increasing awareness of environmental concerns on the other, may account for the observed trend.

In view of the substantial increase in the production and

TABLE III

The Extent of Recovery of Added Nonionic Surfactant (NP_{10}) from Raw Municipal Sewage Effluents in Israel

Sewage location	NP added (mg)	NP recovered[a] (mg)	Recovery (%)	Average recovery (%)
Oranim (O)	2.5	2.25	90.0	91.9
	2.75	2.71	98.5	
	5.0	4.66	91.2	
	5.5	4.85	88.1	
Neve Shaanan (NS)	1.0	0.98	98.0	94.3
	2.0	1.50	75.0	
	2.75	3.02	110.0	
Haifa Municipal Sewage Treatment Plant (HMSTP)	1.0	1.18	118	110
	2.0	2.38	119	
	3.0	2.88	96	
	4.0	4.42	110	
	5.0	4.97	109	

[a]Using the sublation procedure for concentration and the CTAS method for the recovered nonionic determination.

TABLE IV

Nonionic Surfactants' Content[a] of Selected Typical Municipal Sewage Systems in Israel

Location	Run	Nonionics concentration mg/L	Average nonionics contents
Oranim (O)	1	0.7	0.85
	2	0.8	
	3	0.8	
	4	1.1	
Neve Shaanan (NS)	1	2.7	3.2
	2	2.9	
	3	3.2	
	4	4.1	
Haifa Municipal Sewage Treatment Plant (HMSTP)	1	3.4	3.8
	2	3.5	
	3	3.5	
	4	4.0	

[a]In raw sewage.

TABLE V

Comparison of Nonionic Surfactants' Concentration in Some Selected Municipal Sewage Systems

Location	Year	Nonionics concentration (mg/L)
Haifa (Israel)	1975[a]	6.3
(HMSTP)	1981[b]	3.8
Neve Shaanan (Israel)	1975[a]	12.2
(NS)	1981[b]	3.2
Sewage treatment plant (U.K)	1976[c]	5.35
River Lee	1976[d]	2.7
	1978[d]	1.3

Determined in all cases by using the CTAS method.
[a]Ref. 4.
[b]This study.
[c]Ref. 24.
[d]Ref. 28.

use of nonionic surfactants, the increased need for the reuse of available water resources of almost any quality for a variety of purposes (irrigation, industry and so forth) and the increasing implementation of regulatory environmental legislation, the residuals of nonbiodegradable, nonionic surfactants in municipal sewage systems constitute a large problem. Constantly monitoring the content of nonionic surfactant of municipal sewage systems and other available water resources and also searching for routes to limit the production and use of hard nonionic surface active agents is necessary.

We are gearing the next phases of our project toward this end. Currently, we continue to work on the effect of the presence of anionic detergents on the determination of nonionic surfactants in sewage, to be followed by the determination of the biodegradable/nonbiodegradable ratio of nonionic surfactants present in our municipal sewage. Thus, we hope to provide reliable methods for monitoring supervision and control of nonbiodegradable, nonionic detergent concentration in sewage effluents and water resources. We also plan to develop model basis-formulations of cleansing agents based on biodegradable nonionics and thus promote the voluntary switch of our industry from hard to soft nonionics.

Our efforts seem to us to be not only a vital step toward any legal action taken, but also a meaningful contribution toward the constructive solution to the problems of one critical aspect of water quality and the design and planning of alternatives for its useful reuse in the future. The ultimate goal is, therefore, the improvement of water quality in primary and secondary resources and recycled water.

ACKNOWLEDGMENT

This project was supported by the EPA of Israel, the Office of the Interior.

REFERENCES

1. Bluestein, B.R., and R.D. Cowell, JAOCS 58:173A (1981).
2. Ninth Report of the Standing Technical Committee on Synthetic Detergents, H. M. Stationary Office, London, 1967.
3. Thirteenth Report of the Standing Technical Committee on Synthetic Detergents, H. M. Stationary Office, London, 1972.
4. Narkis, N., and S. Henefeld-Furie, Water and Sewage Works 69 (March, 1977).
5. Zoller, U., and R. Romano, Environ. Inter. 9:55 (1983).
6. Arlosoroff, S., A Paper Presented in the United Nations Water Conference, Mar del Plata, Argentina, 1977.
7. Narkis, N., and B. Ben David, Research No. 013-445, The Technion R&D Foundation Ltd., and Water Commissioners Office, Israel, 1980.
8. Zoller, U., O. Weintraub and N. Havatselet, The Sci. Total Environ. 15:51 (1980).
9. L. Kravetz, JAOCS 58:58A (1981).
10. Soap, Cosmetics, Chem., Spec., 52 (January, 1980).
11. Surfactants in North America to 1987, Colin A. Houston and Assoc., Inc., Mamaroneck, NY, 1979.
12. Synthetic Organic Chemicals, U.S. Production and Sales, 1978, U.S. Govt. Printing Office, Washington, DC, 1979.
13. McKenzie, D.A., JAOCS 55:93 (1978).
14. Synthetic Detergents II: Nonionic Detergents, Notes on Water Poll., Ministry of Technology, England, No. 34, Sept. 1966 and Swisher, R.D., JAOCS 40:648 (1963).
15. Zoller, U., Tenside/Detergents 16:135 (1979).
16. Eitan, G., A Paper Presented in the 2nd International Conference on Ecology and Environmental Quality, Jerusalem, May 24-26, 1983.
17. Idelovitch, E., and M. Michail, Munic. Wastewater Reuse News 42:12 (1981).
18. Horowitz, M., and A. Givelberg, Pestic. Sci. 10:547 (1979).
19. Watts, A., Proc. Soc. Anal. Chem. 5:54 (1968).
20. Milwidsky, B.M., Analyst, 91:377 (1969).
21. Wickbold, R., Tenside/Detergents, 9:173 (1972).
22. Patterson, S.G., E.C. Hunt and K.B.E. Tuckers, J. Process. Inst. Sewage Purific. 190 (1966).
23. El Khateeb, S., S.M. Hassan, A.K.S. Ahmad and M.M. Amer, Tenside/Detergents 16:27 (1979).
24. Boyer, S.L., K. Guin, R.M. Kelley, M.L. Mausner, H.F. Robinson, T.M. Schmitt, C.R. Stahl and E.A. Setzkorn, Environ. Sci. & Tech. 11:1167 (1977).
25. Milwidsky, B.M., Practical Detergent Analysis, McNair-Dorland, New York, 1970.
26. Mausner, M., J.H. Benedict, K.A. Booman, T.E. Brenner, R.A. Conway, J.R. Duthie, L. Garrison, C.D. Hendrix and J.E. Shewmaker, JAOCS 46:432 (1969).
27. Organization of Economic Cooperation and Development (OECD) Report: Pollutions by Detergents, Paris, France, 1971.
28. 20th Report of the Standing Technical Committee on Synthetic Detergents, H. M. Stationary Office, London, 1980.

[Received March 24, 1983]