FIELD TESTS OF LAS BIODEGRADABILITY

A SYMPOSIUM HELD AT THE
20th ANNUAL INDUSTRIAL WASTE CONFERENCE
PURDUE UNIVERSITY, MAY 4-6, 1965

THE SOAP AND DETERGENT ASSOCIATION
SCIENTIFIC AND TECHNICAL REPORT NO. 2
SEPTEMBER, 1965

Grateful acknowledgment is made to
DON E. BLOODGOOD
Professor of Sanitary Engineering
and Chairman, Industrial Waste Conference
Purdue University, Lafayette, Indiana

THE SOAP AND DETERGENT ASSOCIATION
295 Madison Avenue, New York, New York 10017

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INTRODUCTORY COMMENTS

P. J. WEAVER
Director of Sanitary Engineering Research Services
Procter & Gamble Company, Cincinnati, Ohio

I SUSPECT that a goodly part of this audience is very conscious of the various questions which have been raised concerning detergents and their role in water pollution problems. Undoubtedly, most of you are aware of the large-scale investigatory program undertaken by the detergent industry, both in research aimed at truly defining the problem, and in research directed towards developing new surfactants which would be adequately treatable. Perhaps most of you also know that the detergent industry, after what has now amounted to about a decade of basic research and development, has been successful in developing a new surfactant, LAS, and that the industry is currently converting from the old difficult-to-degrade ABS to this new biodegradable material. This conversion program is expected to be completed by the middle of this year.

It has been suggested by some that this is the largest voluntary effort directed towards overcoming a water pollution problem ever accomplished by a single industry; and with a cost estimated at over $150 million dollars, I think we can be persuaded to agree. In any event, the detergent industry is convinced that the change from ABS to LAS is a significant improvement so far as treatability of detergent wastes is concerned, and is an adequate answer to any pollution problems attributable to detergent products.

It is hard to estimate how many experimental products were examined in various laboratories before the most promising candidate could be singled out, but certainly it must be close to a thousand. Of course, this screening had to include many aspects other than the question of waste treatment biodegradability or treatability. But as the promising candidate came more and more to the fore, its testing was expanded and accelerated on all sides to be as sure as possible that there would be no slip-up with the material. On the treatability side, more and more laboratory tests were brought to bear, and eventually the scale of testing was raised to just about the ultimate that one can expect – actual use-testing in the field.

This symposium is being held today to discuss four separate field tests which have been carried out to evaluate the treatability of LAS. Two of these tests were sponsored by individual companies and two were sponsored by the Soap & Detergent Association. Each study was carried out under the supervision of a different university, and will be discussed today by the following gentlemen in this order: Professor G. P. Hanna will discuss the Ohio State project carried out near Columbus; Professor Charles Renn will discuss the Johns Hopkins study carried out at Woodbridge, Virginia; Professor John Knapp will cover the Virginia Military Institute project at Manassas Air Force Station in Virginia; and Mr. Paul Knopp will discuss the University of Wisconsin study at the Kettle Moraine Boys School near Plymouth, Wisconsin. These speakers will be followed by Mr. T. E. Brenner, Research Director of the Soap & Detergent Association, who will recap and put into single perspective the findings of the four studies.

A FIELD STUDY OF LAS BIODEGRADATION BY MODIFIED ACTIVATED SLUDGE*

GEORGE P. HANNA, JR., P. J. WEAVER,
W. D. SHEETS, R. M. GERHOLD

Introduction

A sixteen month study sponsored by the Procter and Gamble Company has been completed at The Ohio State University confirming, by extended field tests, the biodegradability of the new linear alkyl sulfonate (LAS) and comparing its biodegradability to that of alkyl benzene sulfonate (ABS) based products now being replaced by LAS.

The evaluation was made on a full scale modified (extended aeration) activated sludge plant treating an essentially domestic waste containing residues of household synthetic detergents.

Test Site

The area selected for the experiment was the Brookside Estates located on the north edge of Columbus about half way between the Scioto and Olentangy Rivers. The site selection was influenced by the fact that this development was a relatively stabilized community of adequate size with its own modified activated sludge sewage treatment plant treating an essentially domestic waste. (Figure 1)

The development consisted of 88 homes in the $30,000 plus price range, all of which were completed prior to the field test. Little house construction activity was evident during the study period and no increase in the number of families occurred during this time.

Test Products

Each home was provided with detergent formulations of known composition during the entire study period in order to insure that a uniform type of surfactant was being evaluated. Several detergent products containing either LAS or ABS for the different periods of the test were packaged and labeled to indicate detergent type, (such as all purpose normal sudsing detergent, liquid dishwashing detergent, etc.), directions for use, net weight, and name of manufacturer (Procter and Gamble).

Treatment Plant

The original treatment plant was completed in 1955 and utilizes a modified activated sludge or extended aeration type of treatment. The design was based on a 24-hour aeration period and a four hour final settling period with excess sludge storage. No primary settling is provided, the comminutor flow passing directly into the aeration tank. Two aeration tanks of 15,000 gallons capacity are provided, and air is supplied by two 100 cu. ft. per minute rotary blowers. From the aeration tanks, the flow passes to the final settling tank of 5,000 gallons capacity.

The subsequent addition of a 10,000 gpd waste flow from an adjacent country club and anticipated growth of the subdivision, led to enlargement of the treatment facility in 1962. This anticipated increased growth, however, had not materialized by the end of the study, and the entire work reported is based upon operation of the original plant. Figure 2 is an

*This is a condensation of the article entitled "A Field Study of LAS Biodegradation" by George P. Hanna, Jr., P. J. Weaver, W. D. Sheets, and R. M. Gerhold appearing in two parts in the November and December, 1964 issues of WATER AND SEWAGE WORKS.

Messrs. Hanna and Sheets are Associate Professors, Water Resources Center, The Ohio State University. Messrs. Weaver and Gerhold are associated with the Product Development Division, The Procter and Gamble Company.

aerial view of the entire waste treatment facility, and Figure 3 is a schematic diagram of the plant used throughout the study.

Effluent Quality

The receiving stream is variable in flow and during dry periods, nearly the entire flow can be traced to the plant effluent. The stream enters a residential area about three quarters of a mile from the plant and continues through this type of area to its confluence with the Olentangy River. The water appears clear, is high in dissolved oxygen, produces no odors, and supports an abundant variety of biota.

Sampling Methods

Sigma pump units with variable speed drive were found to be very satisfactory for automatic collecting of raw influent and final effluent composite samples. Composite samples were collected twice per week, and toward the end of the study this was increased to three times per week. It was not possible to achieve the automatic sampling proportional to the flow. The samples were therefore run at a set rate for the 24 hour period. It is not believed that this has any important effect on the effluent samples since effluent flow generally was evened out. However, it does have the effect of somewhat "diluting out" the influent composites so that measured surfactant concentrations as well as other analyses may be lower than the average level. This in turn results in a lower "percentage removed" for any given measurement than is actually the case.

Operational Factors

Plant operations covered by this report began in December, 1962 and extended through April 30, 1964. The total study is divided into operational periods based on type of surfactant product furnished, variation in aeration times (detention), and variation in mixed liquor suspended solids. Parameters of operations selected for monitoring efficiency of biodegradation were surfactant, BOD, and COD, all expressed on a per cent remaining basis. Data were also recorded on flows, and air and sewage temperatures.

Test Periods

From September to December, 1962, preliminary studies served to develop sampling and analytical techniques, and to obtain key information relating the plant operation. This preliminary data resulted in the decision to carry out the test work only on the old plant in order to effect short detention times. Based upon these preliminary studies, it was further decided to divide the entire program into three major parts:

1. Operation with home owners' normal purchase product
2. A test of ABS biodegradability
3. A test of LAS biodegradability

In each of the tests, attempts were made to vary the condition so that the biodegradability at different aeration times in mixed liquor suspended solids levels would be obtained. Figure 4 is a graphical representation of these runs as defined by per cent remaining surface active agent measured by Standard Methods procedures (methylene blue method, tentative). Also included in this diagram are values representing the average aeration period in hours, the average suspended solids in parts per million, the average BOD removal in per cent and the average COD removal in per cent. Notations at the bottom of this diagram are also included for weather conditions and relative sewage flow. This data is condensed in bar graph form in Figure 5, indicating per cent remaining for all three parameters, surfactant, BOD, and COD. The data is included in tabular form in Table I.

TABLE I
Average Plant Operational Characteristics

Period	Product	Average Percent Removals			MLSS* (mg/l)	Detention (aeration) Time (hrs.)	Average Wastewater Temp. ° F.
		Surfactant	BOD	COD			
I	MBAS	55.0	75.9	43.9	2350	8.9	
II	ABS	32.8	75.1	64.4	1820	12.8	49
III	ABS	7.2	40.5	55.2	1170	5.9	49
IV	LAS	32.5	65.4	51.2	1200	8.5	50
V	LAS	70.2	71.6	45.8	1560	13.4	55
VI	LAS	87.1	90.0	74.0	2760	20.1	62
VII	LAS	93.5	73.6	67.5	2180	24.3	64
VIII	LAS	85.3	59.3	56.2	2130	14.3	54
IX	ABS	52.2	82.3	74.6	3790	13.3	50
X	ABS	42.0	69.8	42.3	1560	18.5	51

*Mixed Liquor Suspended Solids

Under smooth plant operating conditions with a detention period of 24 hours and mixed liquor suspended solids around 2200 parts per million (period VII) LAS removal averaged over 93 per cent. Roughly having that detention time at the same solids level cut LAS removal to 85 per cent (period VIII); and approximately halving both detention time and mixed liquor suspended solids (period V) cut LAS removal to 70 per cent. However, ABS removals under roughly corresponding operating conditions ranged from about 50 per cent down to 30 per cent (periods II, IX, and X). Further, with the exception of period IV, (the acclimation period between ABS and LAS runs), LAS removals were consistently as good or better than overall plant BOD and COD removals. This is in direct contrast to the results obtained with ABS (or MBAS) as the test surfactant. A presentation of surfactant removal data is included in Figures 6 and 7 by simultaneously plotting the three variables of the removal, detention (aeration) time, and mixed liquor suspended solids. By applying the boundary conditions that per cent removal is zero when detention time equals zero, and that the decreasing rates of removal are experienced with significant increase both in mixed liquor solids and in detention time (assuming that 100 per cent removal is not possible) a convex surface can be constructed through the period test data. This appears to be the best presentation of the data considering the three variables. All data points except that representing period X, conform well with the selected surfaces. However, as the highest flow variations with considerable by-passing occurring during period X, the data from this period may be of doubtful accuracy. The ABS surface indicates a much lower degree of removal for corresponding detention times and mixed liquor suspended solids than the LAS surface. While there may not be adequate statistical evidence to justify the development of the surfaces in the two figures, they do give an excellent visualization of the potential differences between ABS and LAS considering the variables involved, and, in the author's judgment, present a reasonable approximation of what would very likely develop if it had been possible to obtain more data.

BOD Surfactant Removal Relationships

In general LAS removals are constantly as good as or better than the overall BOD removals obtained in this type of plant. It is, however, recognized that suspended solids in the final effluent are generally higher in an extended aeration plant than is the case with conventional activated sludge, and that these solids may exert an appreciable BOD. An effort was therefore made to evaluate the BOD exerted by

these solids and to relate BOD removals in terms of soluble BOD in the final effluent with LAS removal.

Figure 8 was obtained by running a regression analysis on the scattered maximum values of BOD versus suspended solids for the several periods. The curve of best fit relating effluent BOD and effluent suspended solids was found to be:

$$\text{BOD, mg/l} = 34.20 + 0.222\ (\text{susp. solids, mg/l})$$

The constant term on the right hand side of the equation, or the BOD intercept at zero suspended solids, is interpreted as the soluble BOD in the effluent. The numerical coefficient of the second term represents the slope of the curve or the ratio of BOD due to suspended solids to the suspended solids in the effluent.

Data extrapolated from this relation based on the slope of the curve would imply that suspended solids in the final effluent contribute about half the BOD load in the final effluent. However, when the LAS was in test and after acclimation had taken place and the plant again operated efficiently, the LAS removals were generally comparable to soluble BOD removals as evaluated from the above relation. This tends to confirm the general conclusion that LAS degradation and the degradation of normal sewage constituents are of the same order.

Summary and Conclusions

A full scale study was undertaken in a modified extended aeration activated sludge plant to evaluate the relative biologic degradation of linear alkylate sulfonate (LAS) versus tetrapropyl alkyl benzene sulfonate (ABS) in an essentially domestic sewage and under normal operating conditions as imposed by natural flow variations and weather conditions. The plant served a community of 88 homes to which the Procter and Gamble Company furnished selected detergent products for use during the study period. The main operational variables considered were type of surfactant, variation in aeration time and mixed liquor suspended solids. Flow variation was considered with respect to its effect on the three main variables.

The general conclusions reached are enumerated as follows:

1. LAS is much improved in biodegradability over ABS for all comparable operating conditions.
2. Efficiency of removal of LAS is proportional to the contact time experienced in the aeration tank. Decreases in removals occur for correspondingly shorter detention times.
3. LAS evidences an acclimatization to aerobic digestion, and an increase in degradability with a corresponding increase in detention time and mixed liquor suspended solids.
4. LAS removals appear to be better than overall BOD and COD removals within the scope of this experiment.
5. LAS removals under conditions when the plant was operating efficiently and after acclimatization were comparable to soluble BOD removals.

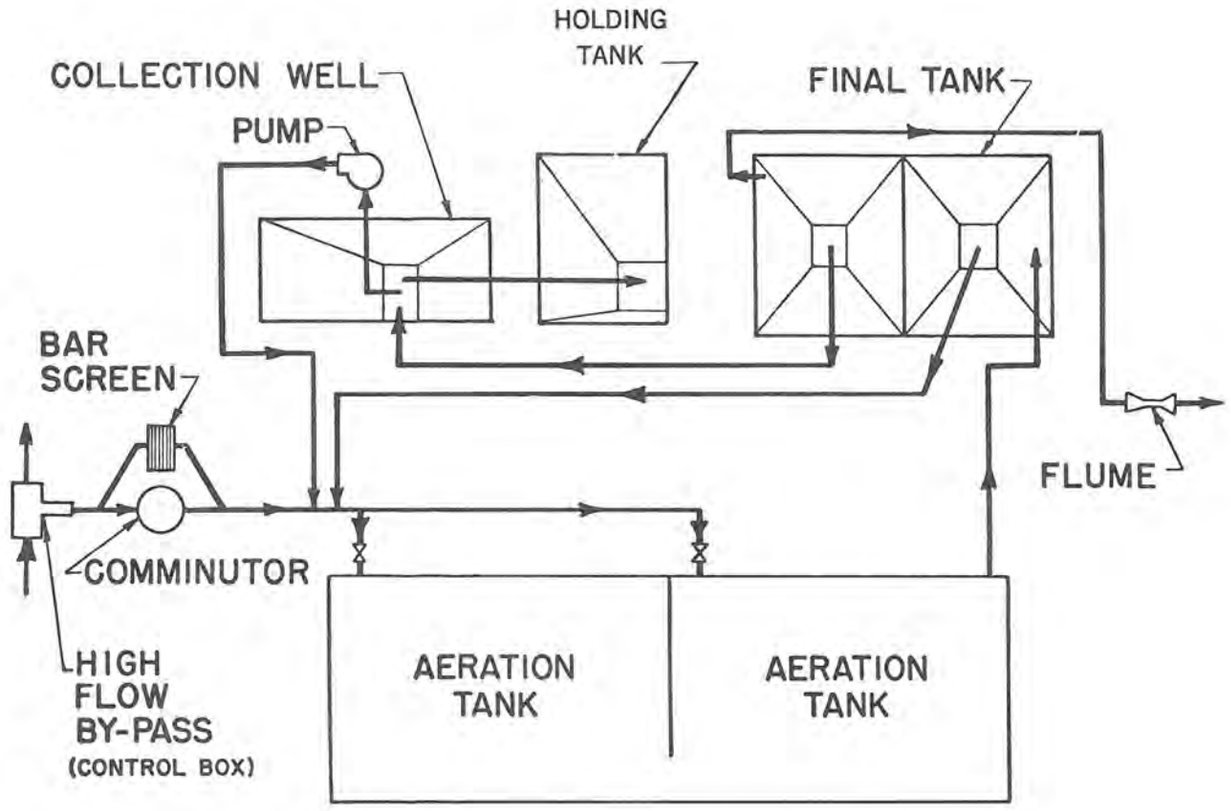
Acknowledgment

Appreciation is expressed to the residents of Brookside Estates for their cooperation in use of products during the test; to the Franklin County Sanitary Engineering Office for providing free access to the plant and its facilities, and for operating the plant as suggested in order to obtain the desired data; and to the Ohio Department of Health for their general cooperation throughout the study.

Aerial view of Brookside Estates and Waste Treatment Plant
Figure 1

Aerial view of Brookside Waste Treatment Plant
Figure 2

(Photos by Procter and Gamble)



BROOKSIDE ESTATES
WASTE WATER TREATMENT FLOW DIAGRAM

Figure 3

BROOKSIDE DETERGENT BIODEGRADABILITY FIELD TEST

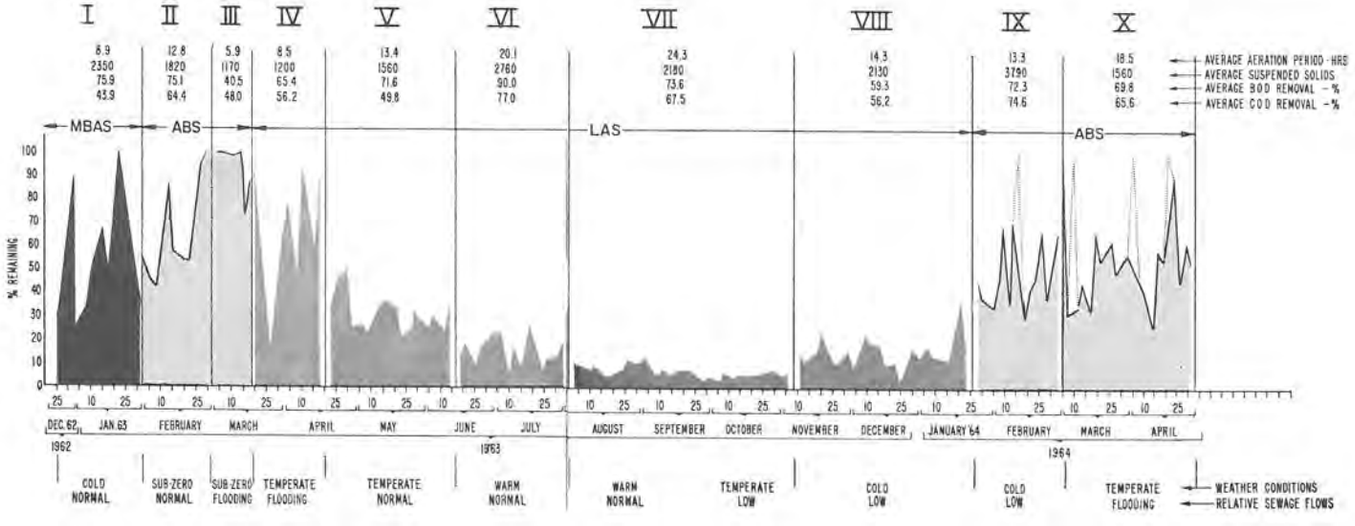
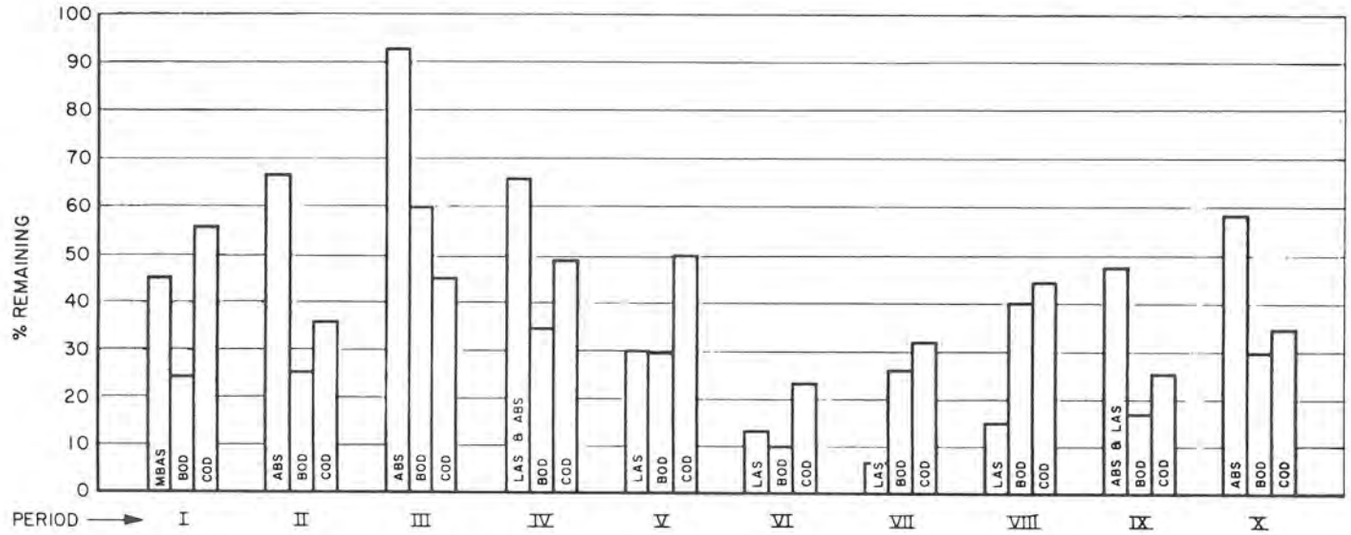


Figure 4

(Courtesy Procter and Gamble)

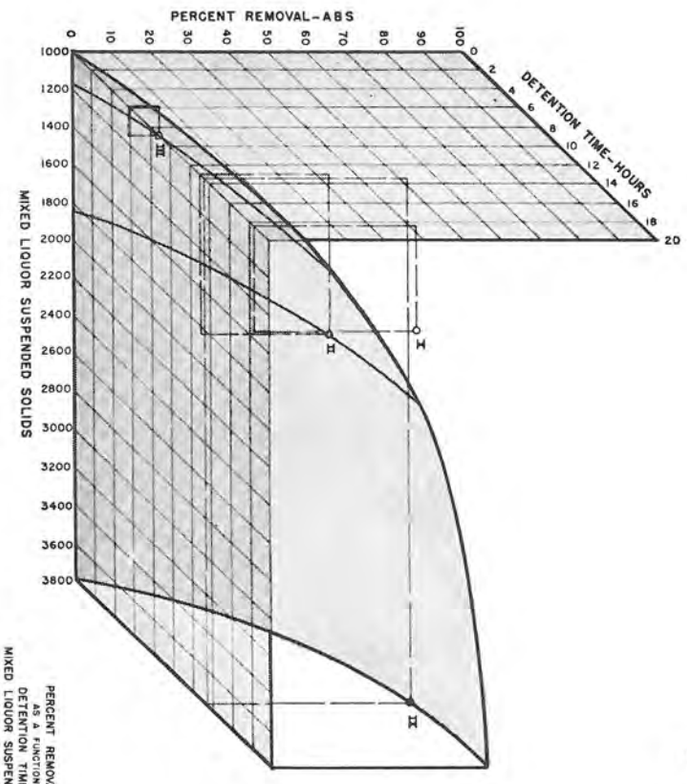
COMPARATIVE SURFACTANT – BOD & COD REDUCTIONS BY TEST PERIOD

M.L.S.S. mg/L	2350	1820	1170	1200	1560	2760	2180	2130	3790	1560
F.E.S.S. mg/L	104	100	49	46	122	39	82	119	74	46



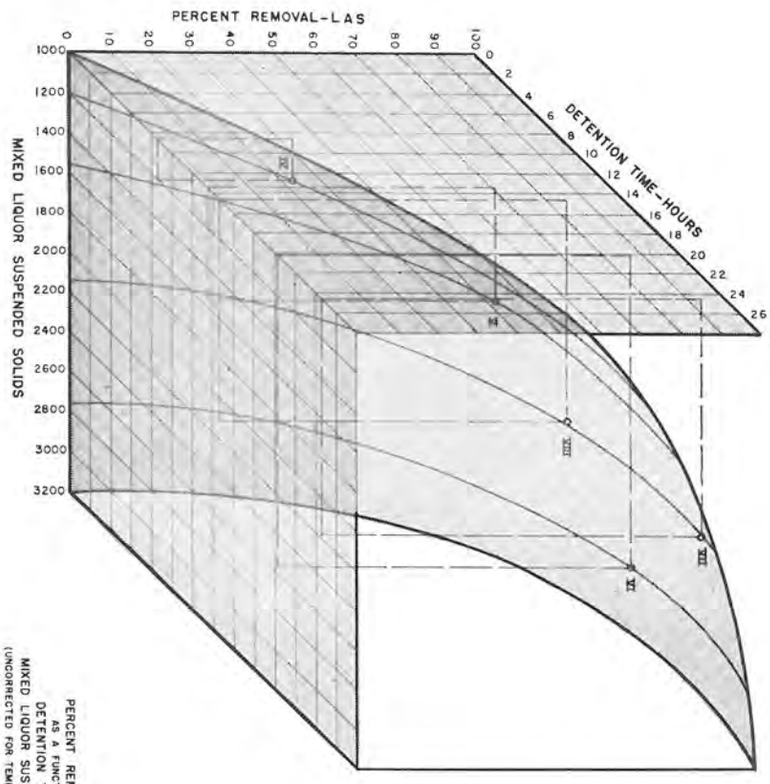
PERIOD →	I	II	III	IV	V	VI	VII	VIII	IX	X
DET TIME HRS	8.9	12.8	5.9	8.5	13.4	20.1	24.3	14.3	13.3	18.5
NO OF WEEKS	5	4	2 ½	4 ½	8	7	14	11	5	8 ½
DATES	12/23 – 1/30	2/1–2/28	3/1–3/19	3/20–4/19	4/20–6/15	6/16–7/31	8/1–11/10	11/11–1/25	1/26–3/2	3/3–4/30
TEMPS.(RANGE) °F		44°–52°	45°–51°	47°–51°	51°–61°	56°–68°	60°–70°	49°–61°	47°–52°	46°–59°

Figure 5



PERCENT REMOVAL–ABS AS A FUNCTION OF DETENTION TIME AND MIXED LIQUOR SUSPENDED SOLIDS

Figure 7



PERCENT REMOVAL–LAS AS A FUNCTION OF DETENTION TIME AND MIXED LIQUOR SUSPENDED SOLIDS (UNCORRECTED FOR TEMPERATURE VARIATION)

Figure 6

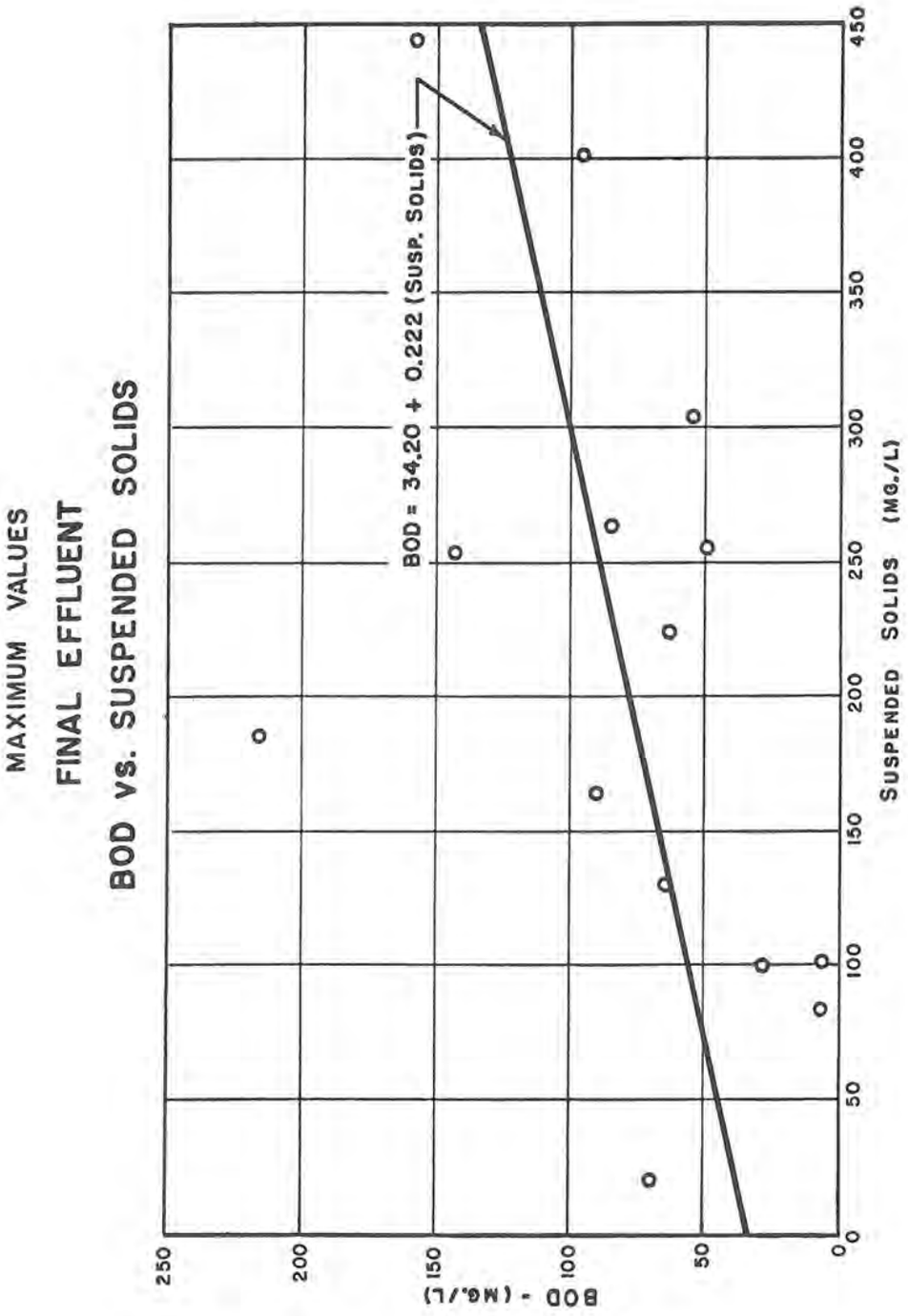


Figure 8

WOODBRIDGE, VIRGINIA, FIELD TESTS OF BIODEGRADABLE LAS DETERGENTS IN EXTENDED AERATION ACTIVATED SLUDGE SYSTEM

CHARLES E. RENN

Professor of Sanitary Engineering
The Johns Hopkins University

A DETAILED account of a successful field study of degradable LAS base detergent materials in a small community extended aeration activated sludge system was published last July.[1] This report was given by the late William Kline of Colgate-Palmolive Company, Dr. Gerald Orgel, and myself, representing part of a cooperative industry-university investigation.

The purpose of this presentation is to emphasize some of the things that we learned about the behavior of degradable detergents that may be useful in the operation of treatment and the design of new plants when LAS base materials come into general use. This was one of the reasons why we wanted a field test. Laboratory studies ranging from river die away tests, shake flask tests, and miniature, continuous feed activated sludge pilot studies had shown us that various LAS materials biodegraded at different rates and that it was possible to distinguish the more readily treated materials. We developed confidence in their treatability in conventional systems.

But conventional treatment can be complicated for the investigator. We knew a little about the British experience at Luton, and we recognized that the business of knowing what goes on in a system as complex as secondary treatment, with unknown storage, variable half life, and other facts of real life could make field tests meaningless, time consuming and expensive.

Our dilemma was this: We could produce experimental materials of the type that we believed that we should produce only in limited quantities at that time. We needed an uncomplicated system of treatment that represented the whole range of existing and probable types of treatment. We wanted tight materials balance control. The system should be free of interferences.

It's surprising how fast we've moved in the past two years. Problems of materials, techniques, processes, and other complications now fall into place. The solutions now seem so reasonable and simple. But they didn't seem that way when we started on the study at Elm Farm Mobile Home Park, near Woodbridge, Virginia. That was in mid-July, 1964.

There is something in luck. Before we secured the cooperation of the Elm Farm Mobile Home community, we spent nearly two years searching for a field test site. We wanted everything — a small community, a stable community, a community without interfering industrial wastes, storm flows, and other disruptions. We wanted privacy. We wanted to carry on the studies without upsetting going waste treatment operations. And we wanted to know where we stood as the work progressed, we wanted to be sure of our results, and we wanted to get the necessary information in the shortest possible time. We would have liked trout, or at least swans, in the receiving waters, if that could have been arranged.

(1) "Destruction of Linear Alkylate Sulfonates in Biological Waste Treatment by Field Test". Charles E. Renn, William A. Kline, and Gerald Orgel, 1964 Journal Water Pollution Control Federation 36 (7) 864-879.

More than anything else, we wanted an adequate, modern waste treatment system, properly maintained, and operated with understanding. This, you will recognize, is the most difficult condition of all to secure in a small community, and that is where we were especially lucky.

I've given a full account of the community and facilities in the original paper. In summary, the advantages that we had for the study were these:

First; we had a stable community of young families, who willingly and enthusiastically cooperated by substituting and using the experimental household detergent materials that we supplied. Since these were packaged as the various Colgate-Palmolive products, this meant at least a temporary switch in brand loyalties. There were 92 to 96 mobile homes in the park during the eight month test period, and the population ranged from 353 to 368 people. Such population stability and general homogenity is exceptional in a small community in modern America.

Second; the Park had a modern, well designed, and well maintained waste water collecting and waste treatment system. Each mobile home was established on a concrete slab and connected to a tight plastic pipe waste collection system. There were no ground water intrusions, road drainage, or other surge producing interferences. Sewage flowed down relatively steep grades in the collecting system and reached the plant in fresh condition; there were no dead spots.

The extended aeration system was more than adequate for the load. This was a single cavitator Yeoman's Brothers Co. unit with approximately 48 hrs. retention time in aeration. Earlier records of performance showed high efficiency of BOD removal – 90% to 95% – and aeration efficiency that maintained excess DO in clarified effluents.

(We had earlier decided that the field tests should be carried out in extended aeration activated sludge systems. Conventional trickling filter and activated sludge systems involving loops through sludge digestion would require very long test periods to secure steady state condition, and materials balance estimates would be difficult at any time because of uncertainties in sludge digestion and its related return loops.)

Third; the treatment plant was well maintained and operated by the park owners themselves. They participated directly in the program and carried out details of the work so that we received many valuable notes and observations on performance and could secure necessary modifications. The plant itself was located in a clean, landscaped area near the park so that it was observable by residents. This made good housekeeping necessary.

Finally; Elm Farm Park had its own store which furnished all daily necessities for mobile home living. The community was five miles from super-markets, and the store furnished many of the day's necessities and minor emergency items for the residents. It was also an information center. This greatly simplified the distribution of detergent materials and records of use.

We began the program with a three week preliminary survey by sampling raw and treated waste through the day and night to establish background conditions of BOD and ABS before LAS substitutions were made. These showed us that influent ABS concentrations varied widely, from low values of 7.5 ppm. to high levels around 32 ppm.; effluents ranged from 2.5 ppm. to 13.0 ppm. BOD concentrations ranged from lows of 88 ppm. to 284 ppm. and daily effluent samples from 11 to 20 ppm. BOD removal efficiencies, smoothed by running averages, ranged from 85% to 95%, while ABS removals varied from 30% to 50%.

All residents shifted to degradable LAS materials at the same time; cooperation was excellent. Monitor samples of the waste influent were free of branched chain materials. The most striking feature associated with the change to LAS materials was the rapid decline in foam on the surface of the aerator. Within the first week of LAS use the foam dropped to the point that the foam breaking sprays could be turned off. We had not anticipated this drastic change; it is possible that the fresh condition of sewage delivered to the plant was a factor in our experience.

Effluent samples showed declining foam levels, and the concentrations of methylene blue active equivalent by which we determined residual anionic detergents dropped dramatically from around 8 ppm. to 3 ppm.

At this point we ran into a series of useful blunders and accidents. We found that we could no longer maintain high excess oxygen in the effluent, and that we had to increase the aeration interval times in the cavitator. The BOD removal efficiency of the system declined steadily despite our efforts to readjust the system, and the methylene blue active equivalent materials in the effluent settled to what seemed to us to be a too high threshold level, considerably above that encountered in experimental laboratory work.

We had anticipated that the inclusion of 10 to 25 ppm. of degradable detergent materials would require more oxygen from an extended aeration activated sludge system, but we had faith that the park system could supply this supplement. We lost considerable time in discovering the conditions that depressed the operation, they were not obvious.

First, we found that more than half of the methylene blue active materials in the effluent were derived from branched chain materials; check samples of influent and of store stocks showed that only linear LAS materials were entering treatment. ABS was present in the effluent and adsorbed on the floc within the aeration basin.

It took us some time to discover that our difficulties with maintaining dissolved oxygen grew from the change in the character of the air-water emulsion generated with LAS bearing waste feed. This was not so obvious. With the new degradable detergent in the system, the air content of the emulsion produced during aeration decreased, and the aeration tank expanded less during aeration. The higher densities of the aerated liquors changed the hydrostatic balance of all other elements in the system, altering the rate of return of liquors over the cavitator cone, the behavior of the clarifier section, and other features. When we discovered this we were able to make adjustments and to bring the system back into optimum hydraulic balance.

At this time, after about eleven weeks of testing, we decided to pump out the old ABS bearing sludge and start the system fresh, taking advantage of our improved hydraulic and aeration adjustments. Within a week, the plant responded by marked and continuing rise in BOD removal efficiencies and a declining ABS free effluent.

Our interval of poor performance had considerable practical value. We had noted earlier in laboratory pilot plant work that different detergent materials were degraded with efficiencies that depended upon the efficiencies of BOD removal; that some bases were more markedly spared by other organics in wastes than other bases. We were able to see from the Elm Farm experience that the efficiency of detergent removal would be modified by overall BOD removal efficiency, but that a system operating in the range 80% to 90% BOD removal could be expected to degrade 80% to 90% of the LAS. If BOD removal could be pushed into the high range of 95% removed, LAS removal was increased into the range of 97.7%.

The delays that were imposed on us carried us late into the autumn, and we made studies of plant performance and detergent removal at low temperatures – at freezing air temperatures and liquor temperatures around 13° C. A month's

study of winter performance showed us that neither BOD removal nor LAS removal was affected adversely by the 10° C. drop in temperature – the efficiency of BOD removal remained in the range of 95% and LAS removal ranged slightly above this, despite increased concentrations of both BOD and LAS in the raw sewage. Compensation was provided by a marked increase in solids in the mixed liquors.

All of this took us into the Christmas season. We found reflections of the holiday mood in the waste influent in rising BOD and LAS concentrations. At this point we decided to see what would happen if we added massive loads of LAS detergent to the waste stream; we brought average influent levels first to 25 ppm., then to 50 ppm., and finally to 75 ppm. LAS – average daily concentration, but added as slugs over an 8 hour period. This was extended through a three week operation.

The first two increments were successfully assimilated, with only a slight rise in LAS concentrations – detergent removal efficiencies rose to 98.5%. On the third day of massive feeding – when we were essentially adding 225 ppm. LAS slugs over 8 hours – the solids in the system became so thick that effective settling could not be secured and the clarifier section overloaded. We had pushed beyond the limits, a full magnitude beyond likely practical waste levels.

Even during this interval, no troublesome foams appeared in the aeration chamber, and the foam breakers were not put in service.

We ended the study by pumping the mixed liquors to waste, and distributing conventional ABS detergent materials in standard packages to the community. As the sludge built, foams began to appear, until these became so heavy after two weeks of operation that the foam breakers had to be placed in service. Methylene blue active substance values in the effluent climbed to 3.5 to 5.0 ppm. We were back where we started, but we had had a glimpse of the future.

BIODEGRADABILITY OF DETERGENTS AT MANASSAS AIR FORCE STATION

JOHN W. KNAPP
Assistant Professor of Civil Engineering
Virginia Military Institute

and

JAMES M. MORGAN, JR.
Director of Research
VMI Research Laboratories

A FIELD STUDY of the comparative removal efficiencies of ABS and LAS detergents was conducted during the summer of 1964 at the Manassas Air Force Station near Manassas, Virginia. The station is a classified installation with a relatively stable population of about two hundred persons. Sewage wastes from barracks, mess halls, and nine dependent homes are treated in a small package-type aeration plant that can be operated to simulate larger conventional treatment plants.

Figure 1 is a schematic diagram of the plant. Sewage enters a wet well after comminution and is lifted intermittently to the aerator tank by one of two 40 gpm. raw sewage pumps. At the design flow of 40,000 gpd. and 1:1 recycle; the system provides 30 minutes detention in the aeration tank, 2 hours detention in the stabilization tank, and 2 hours detention in the clarifier. By a piping modification at the start of the study raw sewage was introduced to the head end of the contact stabilization tank, thus utilizing the combined capacities of aeration and stabilizing tanks as a single aeration basin. After the modification with an average observed flow of 5,800 gpd. and with 1:1 recycle, aeration detention time was 8.5 hours.

Conduct of Test

A three phase sampling program was inaugurated. During Phase I background data were gathered on plant operating conditions and detergent removals when only ABS products were in use. At the beginning of Phase II the plant was emptied and LAS products were distributed station-wide. Phase III was similar to Phase I but with only LAS products in use. To satisfy needs during the LAS phases, several types of detergents were made up by participating industrial corporations. These included a heavy duty laundry powder, a liquid dishwashing product, a liquid all-purpose detergent, and a scouring powder.

During Phases I and III influent and effluent samples were composited continuously every eight hours of the day beginning at 7 a.m., 3 p.m., and 11 p.m. Phase I ran from 29 June to 24 July and Phase III ran from 15 August to 13 September. During Phase II, from 27 July to 14 August, when suspended solids in the aeration tank were accumulating following plant drawdown, a single twenty-four hour composite was collected. A mobile laboratory trailer made available through the cooperation of the Virginia State Water Control Board was parked at the site and personnel of the VMI Research Laboratories, who were on-site throughout the study period, performed all standard sewage analyses.

On each of the composite samples, two determinations were made for MBAS (methylene blue active substance, whether

ABS or LAS). A field determination was made immediately for each sample using a No. 367 Hellige color comparator. One liter volumes of each of the three daily samples were preserved with 1% formaldehyde solution and forwarded each morning to the laboratories of the Johns Hopkins University where they were analyzed for MBAS with a continuously recording laboratory analyzer.

In addition each sample was analyzed for 5-day 20° C. BOD and for suspended solids. Once a day samples were taken for dissolved oxygen and suspended solids in the mixed liquor. Temperature and pH measurements were also taken daily, and foaming potential was checked by a simple shake-test in a 500-ml graduated cylinder. No significant foaming was observed in any of the test phases.

Results

Influent and effluent concentrations of MBAS for the principal test phases are represented by 3-day moving averages in Figure 2. Data are not shown for the three week period following clean-out of the plant when treatment conditions were returning to normal operating levels.

Gradual reduction in influent MBAS levels through Phase I was the result of the station supply office not requisitioning ABS-type detergents after June 15. Stocks on hand were carefully distributed to insure adequate supplies until mid-July. When gratis LAS products were distributed, detergent consumption increased appreciably judging from the rate of depletion of LAS stock levels.

Increased usage did not result in raised MBAS concentrations entering the plant. On the contrary, at the beginning of Phase III the influent concentrations had fallen to unexpected low levels. This condition pointed to the possibility that LAS products were degrading in the sewerage system upstream of the plant. Grab samples collected at upstream manholes were variable and inconclusive. Samples to determine percentage of branched chain material by infra-red analysis were collected and shipped regularly to participating industrial laboratories, but results were not available immediately. After 18 days of observing low concentrations of active material, the decision was made to add a supplemental feed of LAS to the plant. A concentrated solution was siphoned continuously into the influent above the comminutor and wet well. Supplemental loading was continued for the remainder of the study and this period was designated Phase III B.

Table 1 gives average concentration and removals for the principal phases. Effluent concentrations of MBAS during the LAS phases were less than one-half of the effluent concentrations during the ABS phase. Poor LAS percentage removals during the III A phase were caused by the low influent concentrations, but this was reversed in the III B phase when LAS influent concentrations were raised by spiking and little or no increase of MBAS was observed in the effluent.

Distributions of all observed concentrations of MBAS in the influent and in the effluent are summarized in Figures 3, 4 and 5. For the duration of each phase, the curves shown are approximate frequency distributions of concentrations found in 8-hour composites. The curves were constructed by forming an array of all composite concentrations and computing for each ranked item the plotting position $m/n+1$, where n is the total number of observations and m is the serial rank of the item in the array. For comparison, the approximate distributions of BOD concentrations have been added as dashed lines.

The MBAS effluent distribution in Figure 3, showing higher concentrations and greater spread than the effluent distributions in Figures 4 and 5, reflects the relative inefficiency of ABS degradation during Phase I. While the III B distribution in Figure 4 is slightly higher than the III A distribution in Figure 5 because of constant supplemental feeding, the general similarity of the curves suggests a similarity in degradation.

In Figure 4 the unexplained loss of detergents flowing into the plant during Phase III A is evident. However, the position and shape of the distribution in relation to the effluent distribution suggest that detergent concentrations sampled at the plant influent had already undergone considerable degradation. This lends support to the theory that LAS products in use were degrading upstream of the plant.

Leveling-off of the MBAS effluent distributions shown in Figures 4 and 5 for the LAS phases, becoming asymptotic at concentrations between 0.5 and 1.0 mg/1, raised the question of composition of the undegraded residual material. Throughout the LAS phases, samples were preserved and shipped periodically to three industry laboratories for infra-red analysis. The analyses provided information on the percent of branched chain material appearing in each sample. The results of the analyses for eight samples of both influent and effluent during Phase III are given in Table 2. Although the results vary, it appears that the percent of branched chain material increased two to four times from influent to effluent and that the residue of "hard" material in the effluent was in the range of 0.5 to 1.0 mg/1.

The results compare favorably with those of recent similar studies on small activated sludge plants. Average removals calculated from overall average influent and effluent concentrations in several laboratory and field tests are shown in Figure 6. The laboratory-scale miniplants designed by Renn, et al.[1] were fed a synthetic waste material and various LAS products. Field tests in all the studies were run on small aeration plants receiving essentially domestic sewage. In the Kettle Moraine[2] and Brookside[3] studies, the aeration and return sludge rates were varied purposely to observe the effect of changes in plant operating conditions. With the Brookside data, Hannah, et al. explained the variation in average MBAS removals as a function of average concentration of mixed liquor suspended solids and average detention time in the aeration basin. Since BOD is similarly correlated with these variables, it emphasizes that MBAS and BOD removals are correlated only in terms of other underlying variables. Data were not sufficient to examine these relationships further, hence, observed BOD removal remains the best single indicator of treatment conditions, sewage characteristics, and removal efficiencies.

Summary

The three month controlled study at Manassas confirms the improved biodegradability of LAS detergent products. The following observations summarize results of the study:

1. Effluent concentrations of active substance from the aeration-type plant were reduced to 1-2 mg/1 after changing to the use of LAS-based products.
2. Under normal conditions, LAS products appeared to undergo some degradation in the sewerage system upstream from the treatment plant.
3. Degradation was effective and removals excellent when the plant was subjected to supplemental feeding of LAS material.
4. A substantial fraction of the residual active substance in the effluent was branched chain material remaining in the system.
5. A close correspondence existed between the removal efficiency of LAS materials and the removal efficiency of BOD.

These results support the findings of other studies and add to the mounting evidence that the nationwide change-over from ABS to LAS based detergents will provide more readily degradable detergent wastes and lead to a significant lowering of surfactant concentrations in plant effluents.

Acknowledgments

The study was conducted by the VMI Research Laboratories and sponsored by The Soap and Detergent Association, in cooperation with the United States Public Health Service and the United States Air Force. The authors express their gratitude to the personnel of the Manassas Air Force Station for their cooperation, to the Virginia State Water Control Board for providing the mobile laboratory trailer, to Dr. Charles E. Renn of The Johns Hopkins University for his guidance and for arrangements to use the University's laboratory facilities in the Department of Sanitary Engineering and Water Resources, and to Major D. K. Jamison of the VMI Civil Engineering faculty who supervised the field work, and to Messrs. Thomas G. Allen, Floyd H. Duncan, and William H. Hersey, Research Assistants, who performed all laboratory analyses.

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TABLE 1. - MEAN TEST RESULTS BY PHASE

Phase	Sample	MBAS	BOD	COD	Sus Sol
		Concentrations in mg/l			
I (ABS)	Inf	7.8 (7.5)*	217	424	135
	Eff	3.6 (4.0)*	25	128	45
	% Rem	54	88	70	67
III A (LAS)	Inf	2.3 (3.1)*	286	405	164
	Eff	1.7 (1.6)*	27	133	49
	% Rem	35	91	67	70
III B (LAS)	Inf	9.9 (14.0)*	244	449	161
	Eff	1.5 (1.9)*	20	87	41
	% Rem	85	92	81	75

* By color comparator at test site

TABLE 2. - RESULTS OF METHYLENE BLUE AND INFRARED ANALYSES OF ACTIVE SUBSTANCE IN TYPICAL SAMPLES TAKEN DURING PHASE III

Phase	No.	Sample	MBAS (mg/l)	Infrared (mg/l)	Branching (%)	Laboratory
III A	1	Influent	3.4	1.1	25	A
		Effluent	4.4	2.2	50	A
	2	Influent	3.4	4.4	35	A
		Effluent	1.1	1.0	100	A
	3	Influent	2.1	2.2	~16	B
		Effluent	1.3	0.7	~30	B
III B	4	Influent	6.9	8.0	10	A
		Effluent	2.2	1.0	45	A
	5	Influent	5.9	7.8	10	A
		Effluent	2.5	2.2	40	A
	6	Influent	9.6	10.6	24	B
		Effluent	2.0	0.7	-	B
	7	Influent	16.0	13.2	13	B
		Effluent	2.2	1.5	-	B
	8	Influent	18.0	18.4	13	C
		Effluent	1.5	1.0	54	C

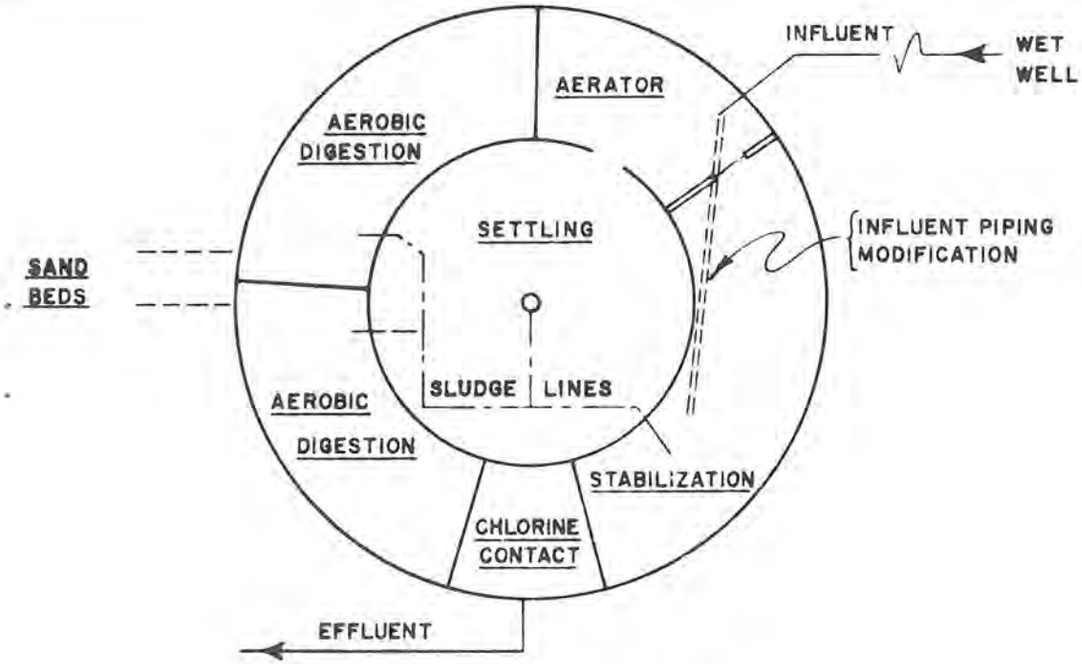

Figure 1. — Schematic Plan of Plant

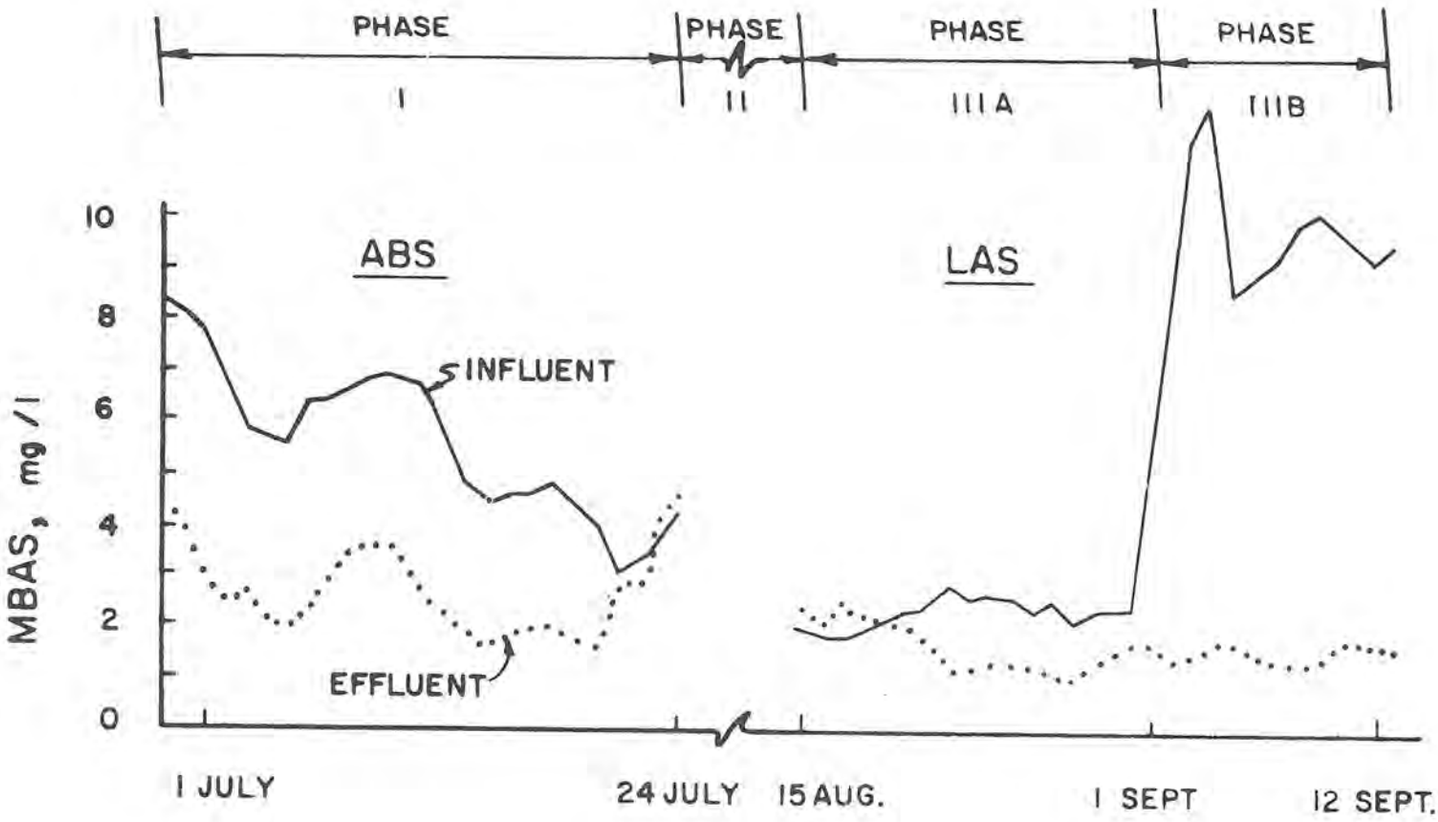

Figure 2. – Average MBAS Results

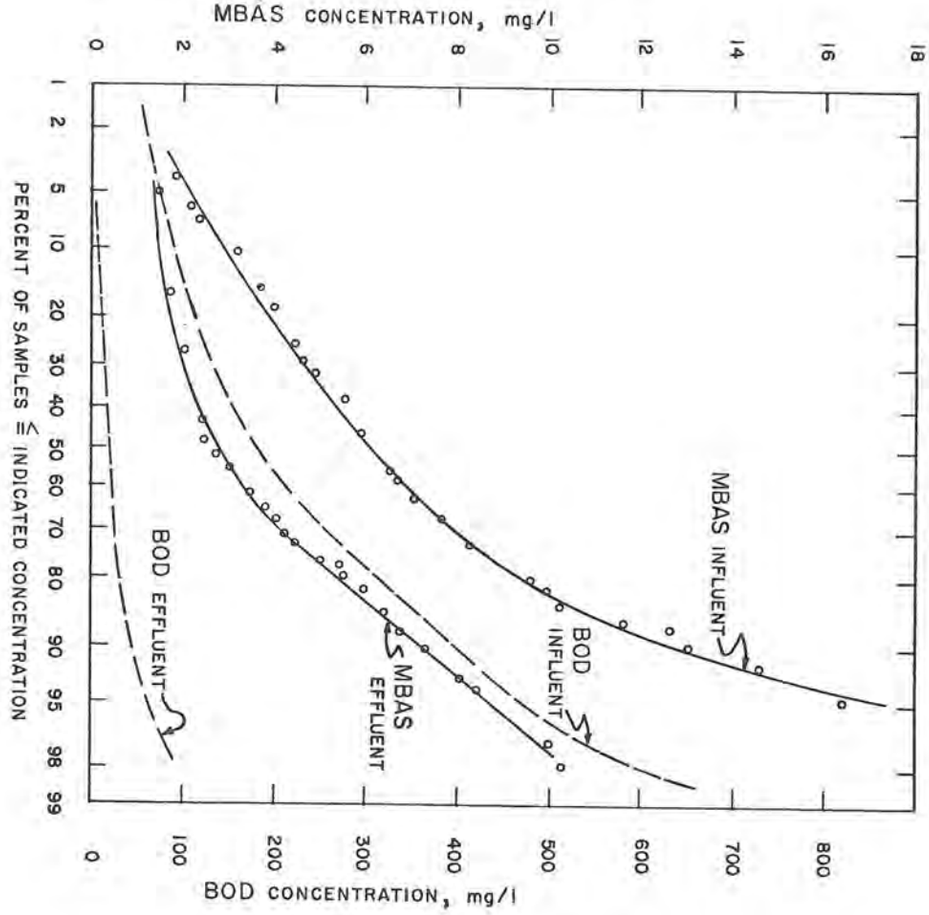

Figure 3.–Distribution of MBAS and BOD sample concentrations–Phase I

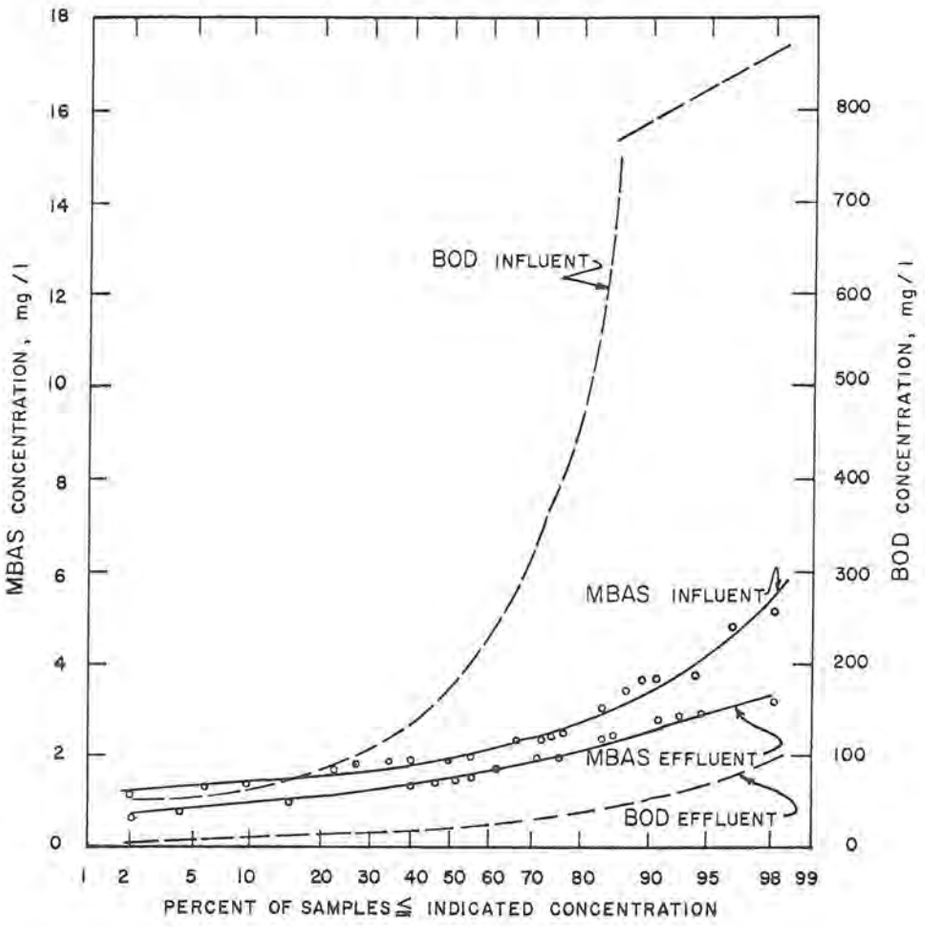

Figure 4. – Distribution of MBAS and BOD sample concentrations – Phase III A

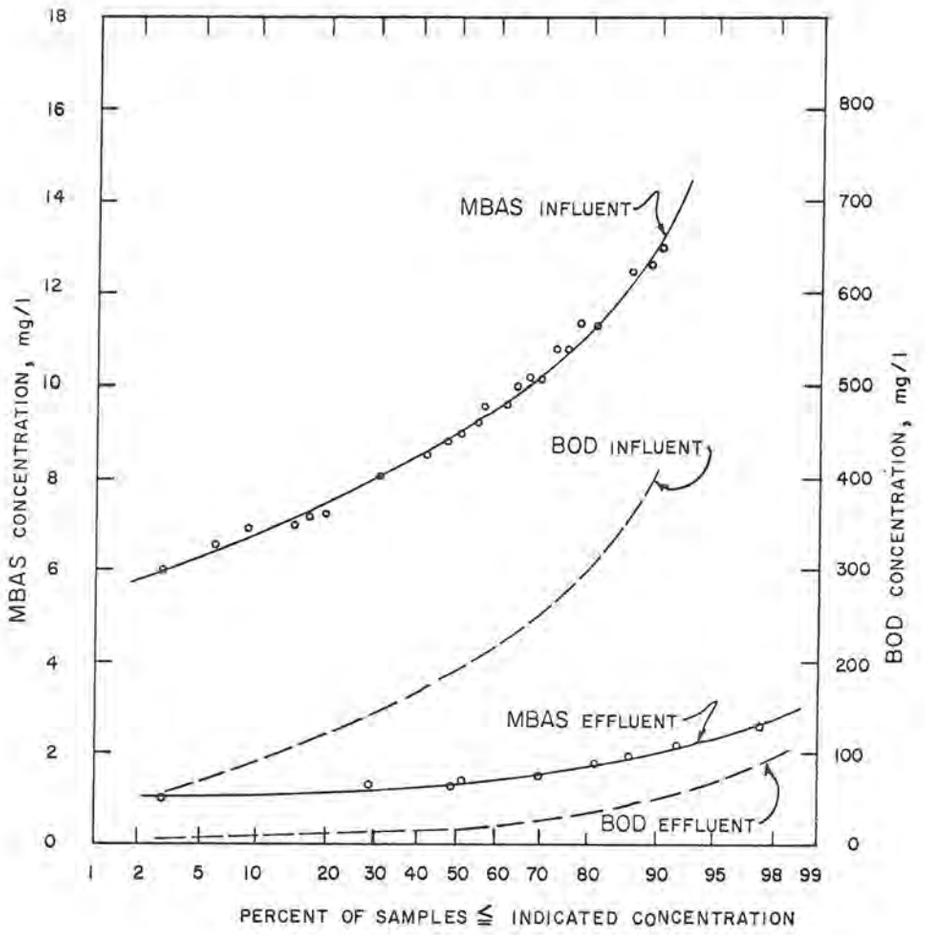

Figure 5. – Distribution of MBAS and BOD sample concentrations – Phase III B

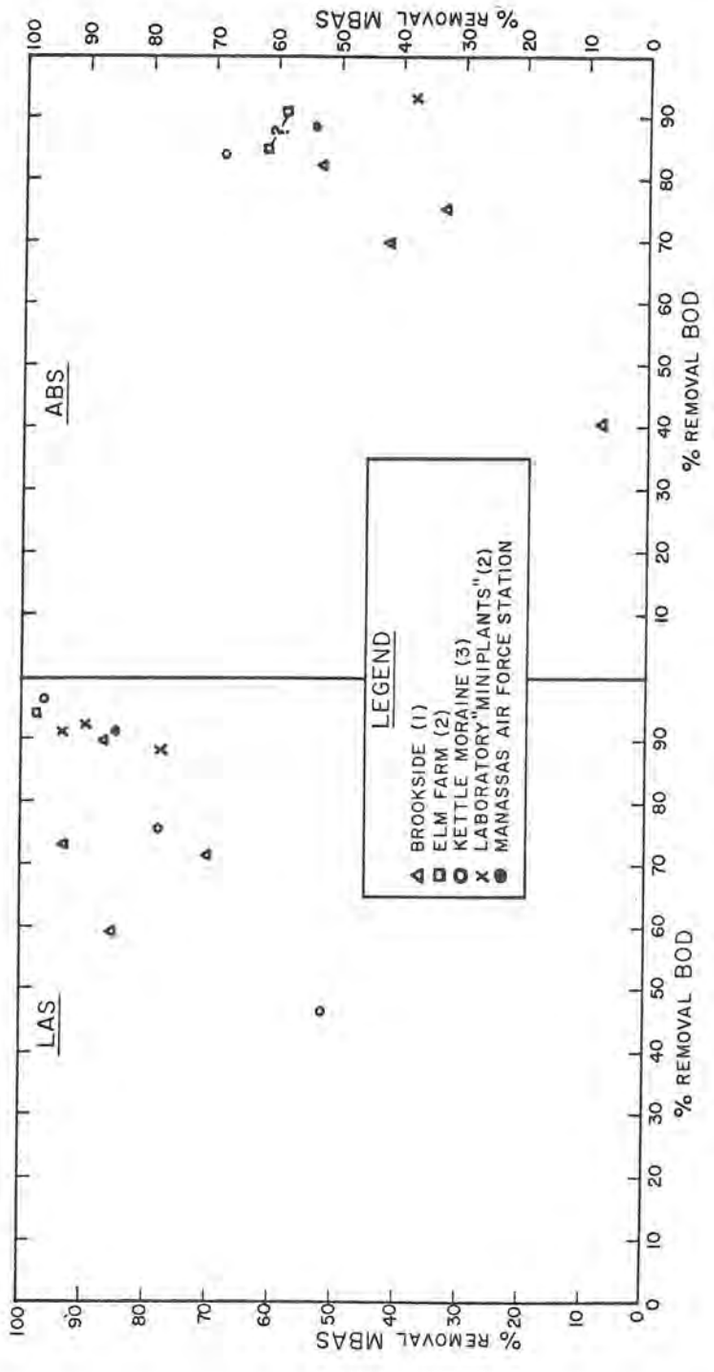

Figure 6. – Comparison of average percentage removal of active material versus average percentage removal of BOD for various studies

THE KETTLE MORAINE SCHOOL FIELD STUDY

P. V. KNOPP, L. J. UHREN, M. S. NICHOLS and G. A. ROHLICH
Civil Engineering Department
University of Wisconsin

I. INTRODUCTION

With the development by the soap and detergent industry of detergents which do not have the biologically persistent properties of ABS (alkyl benzene sulfonate) surfactants, interest has focused on the so-called LAS (linear alkylate sulfonate) surfactant. LAS differs from ABS in that the alkane chain which is attached to a sulfonated benzene ring is not branched; it is this property to which its biodegradable characteristic is attributed.

Field tests of biodegradability of LAS have been reported by Renn, Kline and Orgel[1] and Klein et al.[2] An extensive study by Hanna et al.[3] has been reported recently in which they concluded among other things, that LAS has much improved biodegradability over ABS and that under good operating conditions LAS removal was comparable to soluble BOD removal.

The field test at the Kettle Moraine Boys' School[4] presented further information concerning the performance of the activated sludge process in the removal of LAS surfactants.

A. Purpose of Study

The purpose of the Kettle Moraine field study was twofold: first, the comparison of the removal of ABS and LAS by an "extended aeration" activated sludge plant under field conditions; and secondly, the measurement of the efficiency of LAS removal under so-called "good" and "poor" operating conditions.

B. Description of the School

The Kettle Moraine Boys' School is a state operated "minimum security" institution for delinquent boys. It is located six miles southwest of Plymouth, Wisconsin in the Kettle Moraine State Forest. The school consists of a complex of buildings made up of a control center (administrative offices), a food and supply center, a junior and senior high school, maintenance building, chapel, four staff residences, a motel for staff living on the grounds, and twelve cottages each of which houses 25 to 30 boys. The number of boys at the school varies from 250 to 320 while the staff and employees number approximately 170.

Sewage treatment is provided by an activated sludge unit with the treated effluent being discharged into a pond. The pond has no outlet, thus evaporation and soil absorption balance the incoming flow.

C. The Sewage Treatment Plant

The treatment plant is an activated sludge plant of the extended aeration type. Sewage enters the plant 20 feet below grade and is lifted by two pneumatic ejectors to a small grit removal chamber. The flow then discharges through a comminutor directly into the aeration tank. The aeration tank is equipped with swing diffusers and air diffusion is accomplished with 34 disc type air diffusers. The volume of the aeration tank is 57,600 gallons.

The final settling tank is equipped with sludge collectors and an air lift pump for return sludge. The effluent discharges over v-notched weir troughs. A 90° v-notch weir is installed at the outlet for measuring waste flow. Finally, a chlorine contact tank is provided prior to discharge to the pond.

Air is supplied to the aeration tank by two "Sutorbilt" blowers. These belt driven blowers are equipped with various size pulleys to permit flexibility of capacity. A

separate air system supplies air to the pneumatic ejectors.

II. MATERIALS AND METHODS

A. Methods of Analysis

All analytical techniques were in accordance with the 11th edition of "Standard Methods"[5] with the following exceptions.

1. Methylene Blue Active Substance (MBAS, LAS, ABS).

This method was a modification of the Longwell-Maniece method[6] in which a colored complex is formed between methylene blue chloride and the sodium salt of the anionic surfactant. This chloroform soluble complex obeys Beer's law at low concentrations. Absorbance values were measured with a Coleman model 11 Universal spectrophotometer.

2. Mixed Liquor and Return Sludge Suspended Solids.

This method consisted of filtering 100 ml of sample through an oven dried (103° C.) tared Number 1 Whatman filter paper. The paper and solids were air dried, then dried at 103° C. for two hours and weighed.

B. Sampling Procedures

1. Influent Waste – An influent sampler was installed so that each time the pneumatic ejectors discharged, a small portion (200 to 300 ml) of waste was discharged into a sample barrel. The discharge pipe on the sampler had an inside diameter of one-half inch which allowed for passage of solids in the waste. This sample was collected approximately in proportion to flow.

2. Effluent – The effluent was sampled using a submersible pump set in the effluent weir trough. This pump discharged into a dip-type sampler which collected approximately five gallons of sample in 24 hours. This sample was not collected in proportion to flow.

3. Mixed Liquor and Return Sludge – Grab samples of mixed liquor were taken at the point of maximum turbulence just above the air diffusers at the effluent end of the aeration tank. Return sludge was sampled immediately after discharge over the 90° V-notch weir which was installed to measure recirculated sludge flow.

C. Flow Measurement and Control

1. Waste Flow – The waste flow was measured with a 90° V-notch weir located at the effluent end of the plant. Water level was recorded with a Friez model F-1 water level recorder. Waste flow was estimated from these water levels.

2. Return Sludge – A weir box with a 90° V-notch weir was installed for measuring return sludge flow. Water levels were recorded with a Friez model F-1 water level recorder.

3. Air Flow – No suitable means was available for measuring air flow. It was necessary to make estimates by considering the displacement of the blower and the pulley size used. Reasonable deductions were made for air used by the sludge recirculation air lift pump.

D. Sewage Flow Variation

During the study, two 24-hour sampling runs were made (6-18 and 7-9-64) in order to determine the variation in flow and concentration throughout the day. These runs consisted in collecting two-hour composite samples of the influent and effluent. These samples were analyzed for MBAS, BOD (five-day biochemical oxygen demand), and suspended solids.

The results of one of these runs is shown in Figure 1. (Note the 10:1 scale difference between influent and effluent values.) The importance of proper compositing of influent waste samples is readily seen.

E. Control of Detergents Used by the School

In order to assure control over the use of detergents in the school all LAS (linear alkylate sulfonate) material was dispensed from "Central" Stores. Residents of the four staff houses and the motel were requested to obtain detergents from the school stores during the study. On the designated day of switch-over to LAS material, all commercial products containing ABS material were picked up by a member of the research staff along with a representative of the school. These materials and the commercial products containing ABS that were on hand in the store room were then stored in a separate locked room for the duration of use of LAS material. Similar products specially formulated and containing LAS was substituted for the ABS products. After completion of the test period, all LAS material was picked up and returned to "stores" for inventory. The change over from ABS to LAS material was completed in one day as was the change back to ABS material.

An inventory of LAS material showed that for the period from June 17 to August 14, 1702 pounds of detergent material was used. Analysis of the influent sewage accounted for 123.7 pounds of MBAS material during the period from June 17 to August 14. Based on the inventory of LAS material used during this same period and the quantity of MBAS material contained in the products used, (approximately 7.8% MBAS) the total MBAS material used was calculated to be 133 pounds.

III. RESULTS OF STUDY

A. Procedure and Experimental Plan

The schedule of operation for the duration of the study was as follows:

Phase 1 – May 23 to June 6. Operation under set conditions with local supervision. Composite samples were collected daily and sent to the University of Wisconsin Hydraulics and Sanitary Lab for MBAS analysis. Routine analyses were made by the plant operator. The main purpose of this phase was to set operating conditions so that reasonably steady conditions prevailed at the time of starting Phase 2.

Phase 2 – June 9 to June 17. Operation during this period was under supervision of the research staff. Operating conditions which had been set in Phase I were continued in order to establish removal efficiency of ABS under controlled conditions.

Phase 3 – June 18 to July 7. The use of LAS material was initiated at the school on June 18. The aeration tank was emptied of sludge at the beginning of this period, and was refilled with raw waste. Solids were allowed to build up in the aeration tank under lower aeration rates.

Phase 4 – July 7 to July 29. Operating conditions were set to get maximum removal of LAS by increasing the aeration rate and sludge return rate to those prevailing during Phase 2.

Phase 5 – July 30 to August 14. The aeration rate was cut back during this period to simulate "poor" operating conditions for the system.

Phase 6 – August 15 to September 4. Use of LAS material was ceased on August 14; all LAS material was picked up and replaced with the ABS materials previously in use. Operation conditions were set at those of Phases 2 and 4.

B. Summary of Results

Table 1 summarizes for the various phases of the study the per cent removal of MBAS, suspended solids and BOD, in addition to the DO of the mixed liquor, mixed liquor and return sludge suspended solids, average daily flow, recirculation flow and aeration rate. Figure 4 is a plot of per cent removal of MBAS and BOD. Phase 2 was a period of controlled operation of the plant under supervision of the research staff. Detergents containing ABS were in use. Operation at this time was characterized by the high (approx. 8,000 mg/1) mixed liquor suspended solids concentration in the aeration tank, and high aeration and recirculation rates.

Average effluent MBAS concentration was approximately 1.0 mg/1, and the average MBAS removal was 89.9 per cent while the average BOD removal was 97.2 per cent. Note the high MBAS removal even though ABS material was in use during this period. This may be accounted for by the high suspended solids and the long detention time.

At the beginning of Phase 3, (June 18) the school was converted over to using LAS material, the aeration tank was emptied, refilled with raw waste, and the aeration rate and recirculation rates were reduced. Three days were required to empty and refill the system with sewage. During Phase 3, the mixed liquor suspended solids increased from essentially that of the raw sewage to approximately 3,000 mg/1. The average effluent MBAS concentration was 1.14 mg/1, while the average MBAS removal was 82.4 per cent and the average BOD removal was 87.7 per cent.

During Phase 4, the aeration rate and the recirculation rate was increased to correspond with conditions of Phase 2. The MLSS, however, were 3,500 mg/1 as compared with 8,400 mg/1 during Phase 2. After seven days of operation the effluent MBAS concentration decreased substantially to values less than 0.1 mg/1.

During this period, the plant performance as measured in BOD and suspended solids removal improved so that accurate measurement was difficult. It was further observed and verified by microscopic analysis that during the first few days of Phase 4, a filamentous growth developed in the sludge. The cause of this was not known. The poor settling characteristics resulted in carry over of solids into the effluent between July 10 and 15. The filamentous growth cleared up just prior to the sudden drop in effluent MBAS concentration suggesting that lower effluent MBAS concentrations might have occurred earlier in Phase 4 if the poor settling characteristics had not developed. For this reason, Phase 4 was divided into two periods, 4-A, (July 7 to July 15) and 4-B, (July 16 to July 29), for the purposes of comparing MBAS and BOD removals. During Phase 4-B the average MBAS removal was 96.5 per cent while the average BOD removal was 97.2 per cent.

At the beginning of Phase 5, (July 30), the aeration rate was reduced and the recirculation rate was set to equal that of Phases 2 and 4. The immediate response of MBAS and BOD removal is evident in Figure 2. During this period, the mixed liquor dissolved oxygen decreased to zero and solids were soon lost in the effluent.

The use of LAS was terminated at the school on August 14. Removal of MBAS after changing back to ABS material returned to levels poorer than previously experienced during Phase 2. The average mixed liquor suspended solids during Phase 6 was 2,578 mg/1 as compared with 8,430 mg/1 during Phase 2.

C. Correlation Between BOD and LAS Removal

Phases 3, 4-A, 4-B, and 5 provided results for comparing BOD removal with LAS removal. The average BOD and MBAS removals for these periods are plotted in Figure 3. The data indicate that a good relationship exists between the two with a slope of 45 degrees.

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Table 1.—
Summary of Efficiency and Operating Conditions for Phases 1 through 6

Phase	Detergent Product In Use	Flow G.P.D.	Mixed Liquor SS	Return Sludge SS	Mixed Liquor DO	Aeration Rate SCFM	Recirc. Flow G.P.D.	% Removal MBAS (1)	% Removal SS	% Removal BOD
1	ABS							73.6		
2	ABS	39,700	8,430	12,388	0.5	788	122,000	89.9	94.5	97.2
3	LAS	41,630	2,087	5,261	1.2	646	70,000	82.4	77.0	87.8
4 (2)	LAS	39,373	3,535	5,248	0.8	788	122,000	87.0	85.2	91.5
4-A	LAS	33,541	3,134	4,600	0.3	788	122,000	75.2	77.0	80.1
4-B	LAS	47,534	3,937	5,896	0.8	788	122,000	96.5	91.9	97.2
5	LAS	40,044	3,413	4,360	0.0	450	122,000	50.0	-03.0 (3)	48.7
6	ABS	35,126	2,578	3,506	1.2	788	122,000	65.2	37.6	81.8

(1) Samples collected with commercial Sampler during this phase
(2) Average of phases 4A and 4B
(3) Effluent suspended solids greater in effluent than in Influent

Note: Volume of Aeration Tank = 57,000 gallons

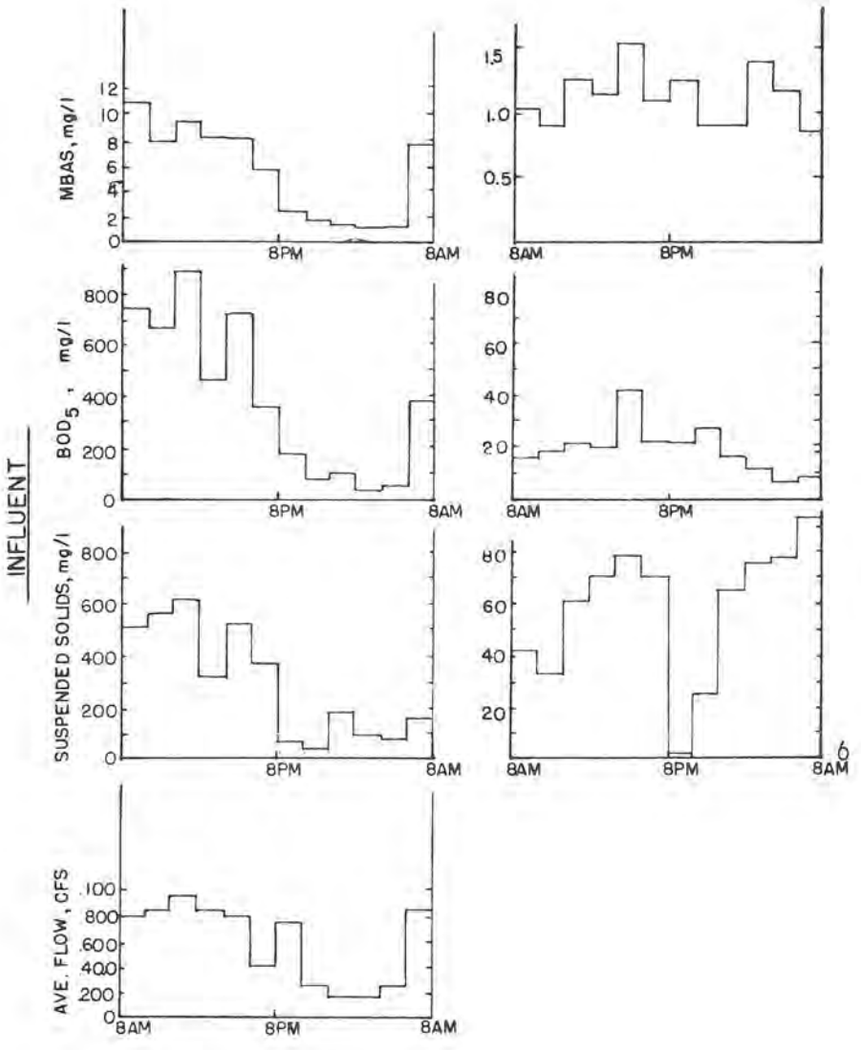


Figure 1. — Variation of MBAS, BOD, Suspended Solids and Flow over 24 hr. period. 7-9 to 7-10-64

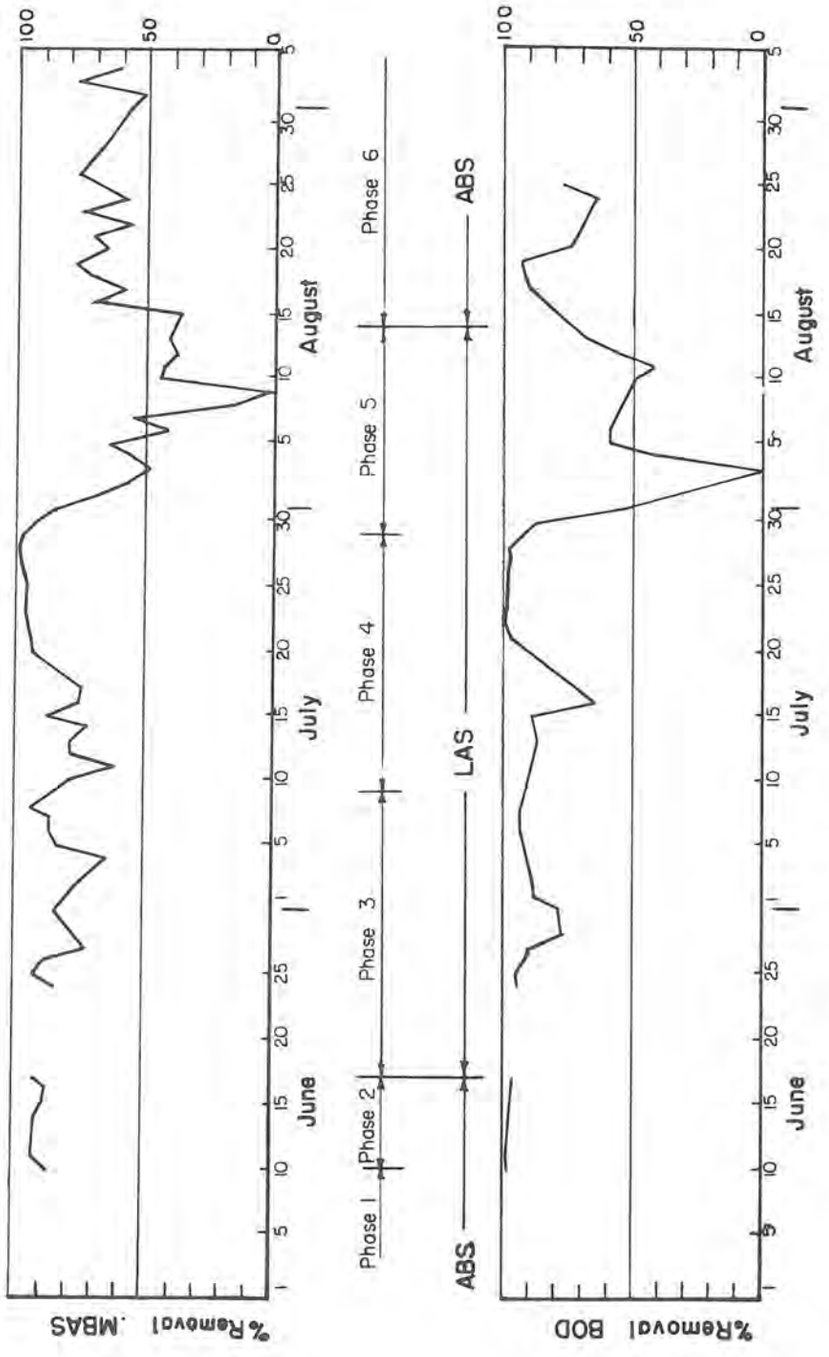


Figure 2. — Per Cent Removal of BOD and MBAS

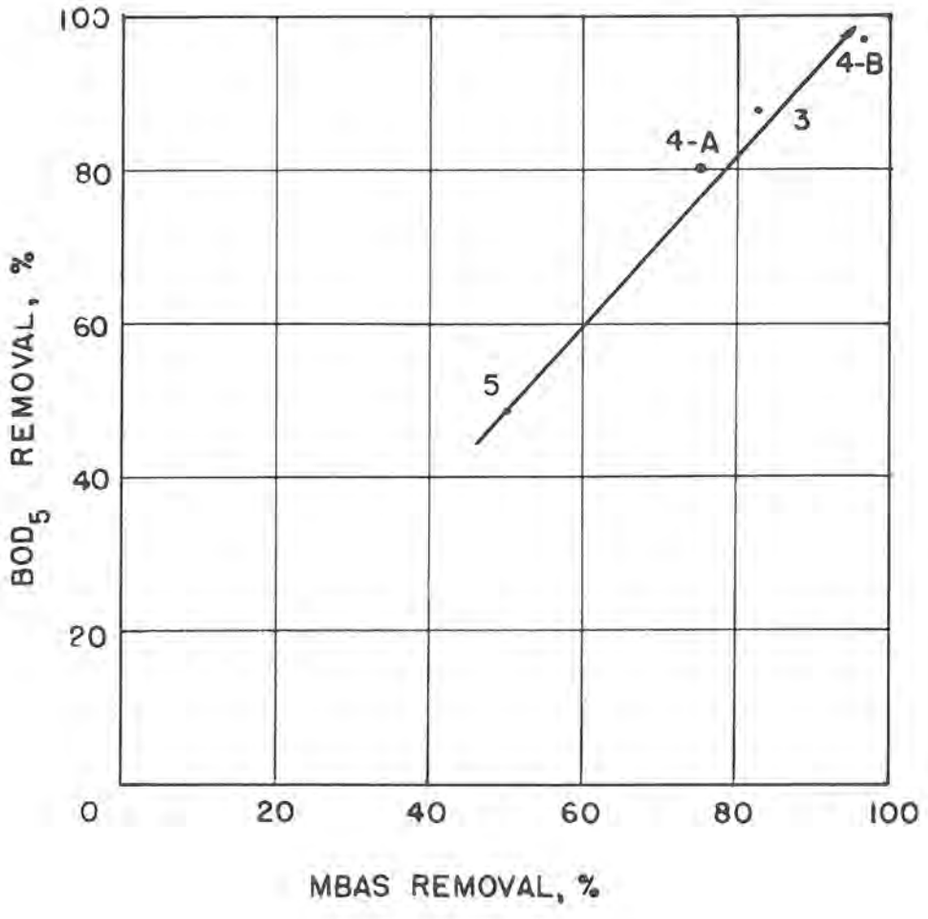


Figure 3. — BOD_5 vs. LAS Removal for Phases 3, 4-A, 4-B, & 5.

SYMPOSIUM SUMMARY

THEODORE E. BRENNER
Research Director
The Soap and Detergent Association

THERE IS very little that can be added to the excellent technical presentations made by the members of the panel. However, a recapitulation of the pertinent data reported on and an up-to-date report on the status of the industry's conversion to LAS would be in order. The American detergent industry expects to have completed its conversion to the use of LAS by June 30th of this year. This conversion marks the culmination of over ten years of research and technological development, and the construction of new plants to furnish the nearly 500,000,000 pounds of LAS needed annually to supply the domestic detergent market.

In addition to the practical aspects of cost and performance in use, the industry needed the assurance that this new material would be as treatable in the field as it was in the laboratory. The answer to this question has, I believe, been given by the Symposium participants.

The industry's aim was to produce a material which would be as readily removed in waste treatment facilities as would other soluble organic constituents in sewage. In practical terms, what we were seeking was a product that would have a 1 to 1 BOD-LAS removal ratio. In a recent report prepared by a blue-ribbon panel for submission to the California legislature, this was referred to as the "treatability" of LAS as opposed to its "biodegradability." I think it is a very accurate term.

In Figure A, I have summarized data collected in the four studies described today to show just how "treatable" is LAS. Any points on or to the left of the theoretical 1:1 removal line would indicate treatability equal to or greater than over-all treatability of the particular waste being studied. As you can see, we are either on or well to the left of the line in practically all cases.

Each of the four treatment plants discussed today employed a variation of the activated sludge process. But it is interesting to note that removals in other systems have been equally impressive. The State of California Detergent Report, for example, makes reference to two studies involving trickling filters; one in England, and the other in the United States.

Tests conducted at Luton, England, showed a 93 percent removal of LAS in comparison with 67 percent removal of ABS. McGauhey and Klein reported 83 to 85 percent removal by trickling filters under transient and uniform loading respectively.

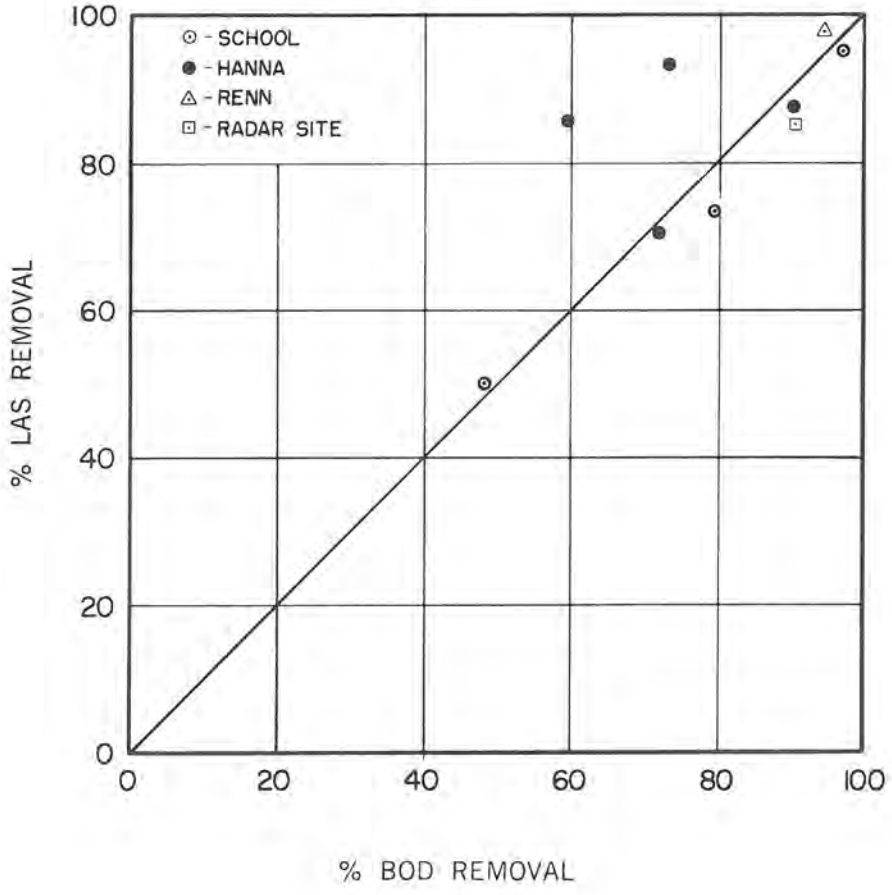
The California group concluded that the standard rate trickling filter should remove 85 to 90 percent of the applied LAS, leaving residuals of only about one-fourth those of ABS. This information, as well as that presented by the other panelists, gives us every indication that LAS has adequate biodegradability for use in the industry's products.

We should not, however, expect unrealistic results from this conversion effort. The full benefits of the conversion will not be achieved where sewage disposal is by cesspools and primary treatment systems.

Detergent foam in streams will become a thing of the past only when adequate sewage treatment facilities are available on a national basis. We are on schedule in our conversion program and unless some totally unexpected event occurs, the

industry should have completely replaced ABS with LAS in its domestic detergent production by June 30th. But this will only take care of a very small, albeit quite visible, portion of the total pollution problem. We are confident that the residues of our new products can be brought below foaming levels after secondary treatment. The more important need will still exist, though, for the planning and construction of modern, effective sewage treatment facilities. In this regard, our industry has a continuing commitment to the long-range support of cleaner water.

With other organizations and agencies who are supporting clean water and conservation programs, we are pledged to continuing studies in the interest of our water resources, which are not limited to the direct effects of our own products.

Figure A

COMPARISON OF
AVERAGE % LAS REMOVAL
WITH
AVERAGE % BOD REMOVAL
FOR SEVERAL FIELD TESTS