FOOD SERVICE WASTEWATER CHARACTERISTICS AS INFLUENCED BY MANAGEMENT PRACTICE AND PRIMARY CUISINE TYPE

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ABSTRACT. *Across the nation, food service establishments using onsite wastewater treatment systems often experience pretreatment system and/or drain field performance problems. This study used statistical analysis of restaurant management practice and primary cuisine type to observe their influence on five-day biochemical oxygen demand (BOD_5), total fats, oils, and greases (FOG), total suspended solids (TSS), and daily flow. Twenty-eight Texas restaurants were involved in the study and were selected to represent a variety of restaurant types. Each restaurant was asked to self-report information on management practices by completing a survey. Wastewater concentrations were determined by analyzing grab samples. Daily flow values were obtained by taking the difference between daily meter readings. Statistical analyses consisted of using multiple regression with backwards elimination and repeated measures using stepwise elimination to determine how management practices and cuisine type may have influenced wastewater characteristics. The analysis also consisted of determining to what extent management practice and cuisine type could be used to estimate BOD_5, FOG, TSS, and daily flow. The number of seats in a restaurant, use of self-serve salad bars, and primary cuisine type were found to play a role in wastewater characteristics.*

Keywords. *Drain field hydraulic overloading, Onsite wastewater treatment, Organic overloading, Pretreatment system overloading, Restaurant.*

Onsite wastewater treatment systems serving food service establishments may experience hydraulic and organic overloading problems. To date, the influence of restaurant management practices and cuisine type on wastewater characteristics, such as flow and composition, have not been statistically evaluated to provide an approach to troubleshoot failing systems or provide sound design guidance. Design guidelines for these systems are typically based on residential applications; however, wastewater strength from restaurants is often higher and more difficult to treat than in a typical residence (Lesikar et al., 2004; Garza, 2004). Factors leading to higher wastewater strength from restaurants include the greater percentage of flow originating from food preparation with items such as meats, fats, oils, greases, and dairy products, and the widespread and intensive use of cleaning agents such as disinfectants, cleaners, floor strippers, and soaps. Another anticipated variable influencing wastewater strength between restaurants is the primary cuisine.

Industry professionals currently rely on methodologies and design values for restaurants that have historically resulted in inadequately designed systems (Stuth and Garrison, 1995) and that do not consider the possible influence of management practice and cuisine type. The purpose of this study is to gain an understanding of what role management practices and cuisine type play in wastewater quantity and composition. This information will assist designers in making the best decisions for designing onsite wastewater treatment systems that protect public health and safety and business profitability.

To date, no studies have been published that apply statistical procedures to determine the relationships of restaurant management practices and primary cuisine type with wastewater characteristics. Only recently has the onsite industry begun to consider the influence of management practices and cuisine type on wastewater and how controlling and implementing management practices can assist designers in providing treatment systems that are more effective and cost efficient. Angoli (2000) discusses restaurant wastewater strength as an issue for onsite wastewater treatment systems due to its direct impact on system performance. Thus, more research is needed to better understand wastewater characteristics and how management practices and cuisine type drive wastewater composition. A poor understanding of the driving forces behind the hydraulic and organic loading of onsite wastewater treatment systems can result in systems that do not perform as intended by the designer.

Adding to the difficulty of designing safe, cost efficient systems are regulations that typically rely on residential

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wastewater strengths and hydraulic loading rates. In the State of Texas, the regulations outlined in Title 30, Chapter 285, of the Texas Administrative Code provide design flow rates for different types of facilities (TCEQ, 2002). TCEQ (2002) regulations identify different types of establishments (e.g., single-family dwellings, hospitals, laundries, restaurants, etc.) and their respective water usage rate in gallons per day. Parameters such as five-day biochemical oxygen demand (BOD5), total fats, oils, and greases (FOG), and total suspended solids (TSS) are not addressed in the regulations. The regulations are limited to providing water usage rates for single-service restaurants and full-service restaurants. This implies that differences in management practices exist between these two categories.

Varying practices and differences in hydraulic loading rates may also yield different wastewater strengths between restaurant facilities. For example, two full-service restaurants may have markedly different business formats: they may have different hours of operation, one may be buffet type and the other menu-based, they may have different serveware washing procedures, etc. In addition, the two restaurants may serve different types of cuisine, e.g., Mexican or Asian.

It may not be possible to directly link a specific management practice to certain wastewater characteristics; however, it would benefit design professionals if trends in wastewater characteristics due to differing management practices and primary cuisine type could be better defined. This would facilitate interpretation of the design guidance provided in state regulations and the published literature; thus, designers would be able to provide better service to the food service establishment industry.

Using certain management practices to reduce wastewater strength can also help maintain wastewater treatment system effectiveness over long periods of time. Furthermore, some management practices may be inexpensive, easy to implement, or simply consist of changing behaviors, yet they may result in less costly system designs or reduced problems for existing systems. The consequence of not having thorough knowledge of how management practices influence wastewater characteristics creates concerns in three areas; increased costs associated with system over-design, compromise of surface and groundwater quality, and public health and safety.

The objective of this research was to statistically evaluate information from self-reporting survey forms and analytical wastewater data to identify trends between management practices and primary cuisine type and effluent quality and quantity.

Materials and Methods

Three independent contract laboratories took wastewater grab samples from 28 restaurants located in Texas. The sampling methodology was established considering restaurant management practices and variation in peak hours of operation during the day. The sampling schedule was derived to capture the time of day when effluent from a restaurant was assumed to be at its highest flow and strongest concentration. In general, peak flow concentration occurs shortly after the noon meal, when meal preparation has occurred and washing and rinsing processes have been initiated. All sampling occurred during June, July, and August 2002.

Field sampling included taking one grab sample daily from each restaurant for six consecutive days, followed by a two-week break, and a second round of sampling over another six consecutive days, for a total 336 total observations.

All samples were taken downstream of the grease trap. Neither facility blueprints nor as-built drawings were available for any of the establishments, and no information was provided by restaurant personnel with regard to commingling of gray- and black-water lines. Therefore, it was not possible to determine whether the samples were taken before or after commingling of wastewater lines. In general, the commingling of the two lines is expected to lower the overall wastewater strength of the facility. For the purposes of this study, the commingling issue was not considered. Restaurant personnel were asked to complete a standardized survey form for this research (fig. 1). It was assumed that the information on the forms was self-reported.

The statistical analysis consisted of using multiple regression with backwards elimination (MRBE) and repeated measures analysis with stepwise elimination (RMASE). The dependent response variables were identified as BOD_5, FOG, TSS, and daily flow. The independent variables consisted of survey information.

Data were transformed to log-normal for BOD_5, FOG, and TSS due to the multiplicative effects of the untransformed data and the appearance of the data to be skewed. In addition, the data were transformed to stabilize variance. The Anderson-Darling test for normality within the SAS statistical software was used to verify the data's distribution. The Anderson-Darling test detects deviations arising from most non-normal distributions (Snedecor and Cochran, 1989). Transformation of the data allows the data to more nearly satisfy the assumptions of a normal distribution and usually makes the deterministic portion of a model a better approximation to the mean values of the transformed response (Mendenhall and Sincich, 2003). The transformed data were tested using the same test and resulted in normal distribution for most of the data. Further analysis of the error (residuals) of those data that did not pass the test for normality revealed that the error was very near normally distributed.

The hypotheses for this study were as follows:

- H_a: $\beta_i \neq 0$ (research hypothesis: at least one management practice (predictor) can be used to estimate wastewater characteristics (response variable).
- H_o: $\beta_1 = \beta_2 = \beta_3 = ... \beta_i \neq 0$ (null hypothesis: not one management practice can be used as a predictor of wastewater characteristics).

The first level of analysis was MRBE. A low probability value ($p < 0.05$) suggests rejection of the null hypothesis (H_o) because it indicates how unlikely it is that a management practice cannot be used as a predictor. If there is sufficient evidence to reject the null hypothesis for a predictor, we could conclude that there is significant evidence to support the research hypothesis (H_a).

All data were entered in the SAS statistical software that fits all the possible models of the form:

$$E(\gamma) = \beta_o + \sum_{i=1}^{p} \beta i \cdot xi \quad (1)$$

where x_i is the ith predictor variable, β is the coefficient determined by the analysis, and γ is the dependent response vari−

Survey

Name of food service establishment ____________________

Address ____________________

Food service establishment description:

Type of food served ____________________

Salad bars/free choice salad dressing? ____________________

Buffet? ____________________

Specialty meals? ____________________

Soft serve ice cream or yogurt machine? ____________________

Self serve drinks? ____________________

How is the food served (paper plates/washable plates, utensils and glasses/take−out)

Types of cooking oils used (liquid or solid) ____________________

Use of preservatives in foods ____________________

Is there a large volume of water used in defrosting food? If so, describe ____________________

Number of seats ____________________

Square footage of the food service establishment ____________________

Average number of meals served M___ T___ W___ Th___ F___ Sa___ Su____

Hours of operation ____________________

Garbage disposal used? ____________________

Dishwashing procedures:

Do they scrape the plates before washing? ____________________

Do they use a commercial dishwasher or wash by hand? ____________________

Temperature of water (high temp, rinse low temp, rinse sanitizing) ____________________

What kind and brand name of detergents used in dishwashing (liquid, powder, or concentrate? ____________________

Does the establishment have a public restroom? ____________________

Does the establishment have low flow fixtures? ____________________

Does the establishment have automatic flush fixtures? ____________________

Clean water inflow:

Ice machine condensate? ____________________

Air conditioner condensate? ____________________

Floor drains? ____________________

After hours cleanup:

Does the after hours cleanup result in wash down water going down a floor drain, and if so, what chemicals are included in the wash down? ____________________

Does the establishment have a kitchen laundry to wash floor mats, tablecloths, and other items? ____________________

Where is cleaning water disposed? ____________________

Where is mop water disposed? ____________________

Grease trap:

Do they have a grease trap or interceptor? ____________________

Size of the trap/interceptor? ____________________

How often is it pumped? ____________________

Location of the sampling point (relative to the grease trap and other business sewers) ____________________

Figure 1. Self-reporting survey form completed by restaurant personnel.

able. The analysis consisted of starting with all management practices discussed in the survey form. Each predictor was methodically evaluated against the response variables, and their particular influence was determined. The SAS model systematically eliminated predictors with a probability value greater than 0.10 and repeated the analysis until the only remaining predictors had probability values less than 0.05, which was determined to be statistically significant for the first level of analysis for this research. A critical probability value of 0.05 was used for this research since the distribution approximates the standard normal distribution after transforming the data. Since all management practices and response variables had to be considered, predictors that survived the analysis, regardless if the predictor survived only in one model (e.g., TSS) and not in another model (e.g., BOD_5), were considered in the next level of analysis.

The next level of analysis consisted of RMASE. Because there were several observations for each restaurant taken sequentially over time, repeated measures analysis was performed (Ramsey and Schafer, 2002). Repeated measures are observations measured over a period of time within the same experimental unit (a restaurant in this case) and between responses (BOD_5, FOG, TSS, and daily flow for this research). Obtaining more than one observation per restaurant can increase correlation within each restaurant as well as between response variables. The repeated measures procedure considers this correlation within and between restaurants to better identify significant predictors. In short, the theory maintains that repeated measures within and between experimental units may be correlated, and this correlation, if it exists, must be taken into account in an analysis, which is lacking in a multiple regression analysis.

Response variables were assumed to have an influence on each other. In other words, since water was the medium that was sampled and the four response variables are water quality and quantity parameters within that same medium, it was assumed that any one response variable could have an effect on the other. With this in mind, the analysis was approached in a manner that considered influences from one response variable to the other. A model that does not consider relationships between variables could produce misleading results since all four variables co-exist in the same medium. In addition, repeated measures analysis considers the unbalanced nature of the sampling (e.g., data having unequal numbers of observations). After the repeated measures analysis was performed, a stepwise elimination was performed on the remaining predictors. This involved removing predictors that exhibited probability values greater than 0.10 and running the repeated measures analysis again until the model stabilized with values less than 0.05 for all remaining predictors.

Low probability values indicate the strength of evidence for the predictive power of a management practice. Cuisine type was treated as a special case since it is a categorical variable and not a numerical or indicator variable, and SAS does not allow for the use of categorical variables in multiple regression. Cuisine was not considered in the first level of analysis but was considered in the more robust repeated measures analysis.

RESULTS

MRBE yielded many predictors (table 1) that could be classified as being statistically significant ($p < 0.05$). However, there is an assumption in using multiple regression that samples are random and independent. For this research, it was assumed that samples were not random or independent. Another problem that arose when considering the probability values as statistically significant was that MRBE did not consider the unbalanced nature of the sampling. Values for all predictors, regardless if they were significant for one response variable and not for another, are shown in table 1. Again, the MRBE analysis was done as a "first cut" analysis to determine what predictors could be listed as candidates for RMASE. As was expected, all predictors could be considered statistically significant because all predictors had a probability value less than 0.05 for at least one response variable. Predictors were expected to have low values because of anticipated high correlation of the repeated measures. This result substantiated the need for the more advanced repeated measures analysis.

As indicated in table 1, several possible predictors were not included in the statistical analysis for a variety of reasons, mostly related to unreliable data or no variability. In the case of dishwashing method, free-choice salad dressing, and serveware type, it was possible to determine the response by the answer provided in another question on the survey form. For the purposes of the research, all questions that asked for specific vendor information, such as brand of detergent used, were not considered. Specific reasons that omitted data were not considered in the statistical analysis are provided in table 1.

All survey responses were positive for the use of public restrooms, so this question was not considered. It should be noted that two of the 28 restaurants were drive-up restaurants, and restroom use in these facilities was expected to be lower than in the walk-in facilities. For the purposes of this research, this issue was ignored. In cases where the survey responses were ambiguous or could be misinterpreted, those responses were not considered. For example, the question "Temperature of water (high temp rinse, low temp rinse, sanitizing)?" could yield ambiguous answers. An answer of "80" to this question could mean that all temperatures were 80° or that 80° is an average temperature or an estimated guess.

Predictors that were classified as significant after the RMASE are shown in table 2. Only cuisine type, existence of a self-serve salad bar, and the number of seats resulted in a non-trivial effect at the 0.05 level.

After determining that the predictor "cuisine" was statistically significant, an analysis was run on cuisine type to determine the respective direction of influence. Results are presented in table 3. Seafood was randomly chosen as a baseline for comparison. A negative sign indicates that the response is lower than the baseline. For example, a predictive equation could be written as follows:

$$\ln(\gamma) = \alpha_o + 0.159(\text{Asian}) \pm \gamma I \qquad (2)$$

where α_o is the intercept, and γ is the *i*th management practice. It can be seen that after simplifying the equation, the cuisine type "Asian" would increase the result by approximately 16%.

It can be determined that restaurants serving primarily Mexican and Asian cuisines tend to exhibit higher BOD_5, FOG, and TSS followed by seafood, single-service American, and full-service American. Daily flow was eliminated from the analysis due to model non-convergence resulting from insufficient data points.

DISCUSSION

Probability values of less than 0.05 from RMASE indicate strong evidence that the listed management practice does in fact impact wastewater characteristics. Numbers of seats, self-serve salad bars, and cuisine type were the predictors determined to be statistically significant in affecting BOD_5, FOG, TSS, and daily flow. The number of seats is often used as a parameter for design of onsite wastewater treatment systems (TCEQ, 2002). The statistical significance for this predictor validates its use as a design parameter.

Study results verify that self-serve salad bars impact wastewater. Hence, removal of the salad bar may be a solution for bringing a non-performing treatment and/or

Table 1. Response variable predictors and related probability values after multiple regression with backwards elimination analysis.

			Probability Values[a]				
	Possible Predictor	Tested	BOD_5	FOG	TSS	Flow	Comments
1	After-hours cleanup (AHC)	Yes	<0.0001	0.0003	<0.0001	<0.0001	--
2	AHC chemicals used	Yes	<0.0001	<0.0001	<0.0001	<0.0001	--
3	Air conditioning condensate	No	--	--	--	--	Unreliable survey responses[b]
4	Automatic flush fixtures	Yes	<0.0001	<0.0001	<0.0001	0.0984	--
5	Buffet-style facility	Yes	0.0002	<0.0001	<0.0001	0.0660	--
6	Cleaning water disposal	No	--	--			Same response for all entities
7	Cuisine type	Yes	--	--	--	--	Repeated measures analysis only
7 a	Full service	--	--	--	--	--	Service type, primarily American
7 b	Mexican	--	--	--	--	--	Primary food type
7 c	Asian	--	--	--	--	--	Primary food type
7 d	Single service	--	--	--	--	--	Service type, primarily American
7 e	Seafood	--	--	--	--	--	Primary food type
8	Detergent brand names	No	--	--	--	--	Confidential information
9	Detergent types	No	--	--	--	--	Unreliable survey responses[b]
10	Dishwashing method	No	--	--	--	--	Determined by item 27
11	Food defrosting	Yes	0.1255	0.0004	0.0319	0.0419	--
12	Free-choice salad dressing	No	--	--	--	--	Determined by item 26
13	Full-service alcohol bar	Yes	<0.0001	<0.0001	<0.0001	<0.0001	Included after site visits
14	Garbage disposal use	Yes	<0.0001	<0.0001	<0.0001	<0.0001	--
15	Grease trap pumping schedule	No	--	--	--	--	Unreliable survey responses[b]
16	Grease trap size	No	--	--	--	--	Not a management practice
17	Ice machine condensate	No	--	--	--	--	Unreliable survey responses[b]
18	Ice-cream/yogurt machines	Yes	0.0006	<0.0001	0.0003	0.8376	--
19	Kitchen laundry	Yes	<0.0002	<0.0001	<0.0001	0.8382	--
20	Lawn irrigation system	Yes	<0.0001	0.2266	<0.0001	0.0017	Included after site visits
21	Low-flow fixtures	Yes	0.0002	<0.0001	<0.0001	0.8467	--
22	Mop water disposal	No	--	--	--	--	27 of 28 reported disposal
23	Oil type used (liquid)	Yes	<0.0001	<0.0001	<0.0001	0.0119	--
24	Oil type used (solid)	Yes	0.4516	<0.0001	0.0332	0.0871	
25	Public restrooms	No	--	--	--	--	Same response for all entities
26	Salad bar (self serve)	Yes	<0.0001	<0.0001	<0.0001	0.0025	--
27	Service type (full or single)	Yes	0.8829	0.6089	0.0025	0.0024	--
29	Self-serve fountain drinks	Yes	0.8363	<0.0001	0.0002	0.7881	--
30	Serveware type	No	--	--	--	--	Determined by item 27
31	Specialty meals	No	--	--	--	--	Definition not provided
32	Use of preservatives	No	--	--	--	--	Unreliable survey responses[b]
33	Wash/rinse water temp.	No	--	--	--	--	Unreliable survey responses[b]
34	Plate scraping	No	--	--	--	--	Same response for all entities
35	Number of seats	Yes	0.0114	0.0020	0.0425	0.4342	--
36	Square footage	Yes	0.0001	0.1705	<0.0001	0.0005	--
37	Meals served	Yes	0.1593	0.9396	0.0436	<0.0001	--
38	Hours of operation	Yes	0.0120	0.2809	0.6400	0.1880	--
39	Location of sampling point	No	--	--	--	--	Not a management practice

[a] Probability value after multiple regression with backward elimination analysis. Analysis assumes random independent sampling without consideration of repeated measures and unbalanced data.

[b] Ambiguous question in survey form.

dispersal system to within its hydraulic and organic loading range. More importantly, special consideration should be given to self-serve salad bars during the design phase of new systems. Salad bars create concern due to many factors, including the high fat content of some salad dressings, disposal of unfinished salads with dressing through the wastewater lines, etc. Cuisine type also influences wastewater characteristics and should be considered when designing a treatment and dispersal system.

This data evaluation suggests that wastewater characteristics from restaurants are affected by management practices. However, due to the limited data and possible subjectivity of self-reported information on the survey forms, there is a need for broader-scale evaluations to develop a more thorough understanding of these influences.

CONCLUSION

Personnel from 28 restaurants in Texas were surveyed to gather information on the cuisines and management practices used in their establishments. Wastewater flows from these same restaurants were monitored to characterize the influence of cuisine type and management practice on flow quantity and quality. A statistical analysis was performed using SAS statistical software that consisted of MRBE and RMASE. The dependent response variables were the analytical results of BOD_5, FOG, TSS, and daily flow, and the independent variables consisted of information from the standardized survey developed for this research.

Table 2. Response variable predictors determined from repeated measures analysis with stepwise elimination.

	Possible Predictor	Probability Value: Before Stepwise Elimination	Probability Value: After Stepwise Elimination ($p < 0.05$)
1	After-hours cleanup (AHC)	0.1110	--
2	AHC chemicals used	0.1070	--
3	Automatic flush fixtures	0.0621	--
4	Buffet-style facility	0.5913	--
5	Cuisine type	0.0368	0.0029
6	Food defrosting	0.1262	--
7	Full-service alcohol bar	0.0720	--
8	Garbage disposal use	0.0956	--
9	Ice-cream/yogurt machines	0[a]	--
10	Kitchen laundry	0.0377	--
11	Lawn irrigation system	0.8569	--
12	Low-flow fixtures	0.0851	--
13	Oil type used (liquid)	0.2118	--
14	Oil type used (solid)	0.1574	--
15	Salad bar (self serve)	0.0400	0.0136
16	Service type (full or single)	0.1589	--
17	Self-serve fountain drinks	0.1837	--
18	Number of seats	0.1350	0.0029
19	Square footage	0.1115	--
20	Meals served	0.8656	--
21	Hours of operation	0.9208	--

[a] Values of 0 resulted from management practice having a high correlation with another management practice. This issue was eliminated through stepwise evaluation.

Table 3. Influence of cuisine type and management practice on wastewater characteristics (BOD_5, FOG, and TSS).

Possible Predictor	Final Parameter Estimate (for use in eq. 2)	Multiplier (relative increase or decrease in wastewater strength)
Cuisine type:	--	--
Primarily Mexican	0.235	1.265
Primarily Asian	0.159	1.172
Seafood[a]	0.000	1.000
Single-service, primarily American	−0.395	0.674
Full-service, primarily American	−0.446	0.640
Self-serve salad bar	0.574	1.775
Number of seats	−0.002	0.998

[a] Arbitrarily set as the baseline for the "cuisine type" category.

The resulting statistical analyses indicated that wastewater composition was affected by management practice and cuisine type. There was statistical validity that self-serve salad bars tend to increase the organic strength of wastewater. The results of the analysis also indicated that wastewater strength tends to be higher for restaurants serving primarily Mexican cuisine, followed by Asian, seafood, full-service American, and single-service American.

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