DISHWATER DETERGENT PHOSPHORUS:

ITS CONTRIBUTION TO PHOSPHORUS LOAD AT A MUNICIPAL WASTEWATER TREATMENT PLANT

A Pilot Study in Lolo, Montana

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I) Introduction:

Nutrient pollution of surface waters by point and non-point sources is a major national environmental issue, and has been the object of considerable work in the Clark Fork-Pend Oreille river basin facilitated by the Tri-State Water Quality Council (the Council). The Council seeks voluntary collaboration to reduce the amount of phosphorus and nitrogen entering the Clark Fork River and Lake Pend Oreille from urban wastewater, industrial wastewater and agricultural non-point sources.

In the 1980's it was recognized that a large proportion of phosphorus loads arriving at municipal wastewater treatment plants originated from laundry detergent phosphates, and a national campaign gradually banned phosphate in laundry detergents in many parts of the country, including parts of western Montana and north Idaho. Recently, it has been recognized that automatic dishwasher detergents, not covered by the original bans, may also be a large contributor to urban wastewater nutrient loads.

In late 2000, the Council's Clark Fork Voluntary Nutrient Program (VNRP) Coordinator initiated an investigation into the role of dishwasher detergent phosphorus in local nutrient pollution. The purpose of this initial investigation has been to estimate the proportion of phosphorus in wastewater treatment plant inflow which originate from automatic dishwasher detergents. Basic information on this topic is lacking, therefore, it was decided to do shelf surveys on phosphorus content in automatic dishwasher detergents, and another survey to quantify the usage of these detergents in western Montana residences. Lolo, Montana, a small community in Missoula County with its own wastewater collection and treatment system, was selected as a site for this survey.

The specific objectives of this study were:

1) Do local shelf surveys of automatic dishwasher detergents and their dosages to estimate phosphorus content, prices and phosphorus load per machine cycle.
2) Do a telephone survey of households in Lolo, Montana, to determine what proportion have automatic dishwashers, how often they use them, and what type of detergent they use.
3) Estimate daily phosphorus load from this source by multiplying dosages by number of dishwashers running per day.
4) Compare the daily phosphate load estimate from residential dishwashers to the total load of phosphorus in the wastewater inflow, to estimate the proportion of the total phosphorus load that originates from this source.

i) Background:

a) Existing Phosphorus Detergent Ban

In 1989, the Missoula City-County Health Department and the City Council banned the use of laundry detergents containing phosphates in and around the City of Missoula. This action was taken after citizen groups campaigned for the ban to protect water quality in the Clark Fork River. This ban followed similar bans in many areas of the United States where the public had become concerned about algae blooms due to nutrient pollution in lakes and streams.

Within the first year of the laundry detergent phosphorus ban, the Missoula Wastewater Treatment Plant measured a decrease of 30-40% in phosphorus entering its treatment facility. Since typical secondary treatment plants remove little phosphorus, the effect of this ban was to reduce by more than 30% the amount of phosphorus discharged from Missoula to the Clark Fork River. Although bans were not passed in all area towns, the staff at the Butte-Silver Bow Wastewater Treatment Plant noted a major decrease in phosphorus entering the plant at the same time, apparently as a result of market forces, as wholesalers shipped mostly phosphate-free laundry detergents to western Montana.

b) Phosphorus in Dishwasher Detergents

The current ban of phosphorus in laundry detergents does not affect dishwasher detergents. Although most liquid detergents for hand-washing dishes are phosphorus-free, detergents for automatic dishwashers typically have a high phosphorus content, as tripolyphosphate is a preferred water-softening agent. Even a cursory examination of products on the shelf reveals that automatic dishwater detergent powders and tablets frequently have a 6 to 8 percent phosphorus content by weight. This is approximately equivalent to the phosphorus content in Miracle-Gro, a common houseplant fertilizer.

The growing use of automatic dishwashers may mean that dishwasher detergent is a major source of phosphate to municipal wastewater treatment systems. One study in Massachusetts estimated that 8-34% of the phosphorus in municipal wastewater may originate from automatic dishwashers (website for Organization for Assabet River Watershed, 2001).

ii) Justification:

By 2004, the State of Montana will develop nutrient standards for surface waters and start doing nutrient allocation through Total Maximum Daily Loads (TMDLs) for affected streams. These measures may put wastewater treatment plants under heavy pressure to reduce nutrient discharge or at least not increase nutrient discharge even as they expand their service areas. Small wastewater treatment plants in the basin were not involved in the original VNRP work, and they generally do not treat their water to remove nutrients.

One inexpensive option for wastewater treatment plants is to limit the amount of nutrients entering their plant. This approach worked for Missoula when phosphate laundry detergents were banned in 1989, which, as mentioned above, reduced the phosphate inflow load to Missoula's wastewater treatment plant over 30% in one year. In order to investigate the potential for further reductions in phosphate loading, it is necessary to estimate the phosphate load from automatic dishwasher detergents which were not affected by the 1989 ban. This information could be of great use to small wastewater treatment plants as they look for new nutrient management options.

II) Study Approach:

The idea for this study originated in discussions between the VNRP Coordinator and wastewater operators, citizens, and university students who were asking how we could reduce phosphorus discharge into the Clark Fork River. The simple idea that household products like automatic dishwasher detergents could be a significant source of phosphorus pollution motivated the Coordinator and a small group of volunteers to investigate the problem. Very little published information was available on the subject, so the group decided to do its own "field" research. It was decided to survey the phosphorus content of automatic dishwasher detergents, and then to estimate use of these detergents through an interview-type telephone survey. These data would be combined to estimate the wastewater load of phosphorus originating as dishwasher detergents in a pilot study area.

i) Strategy: Residential Use vs. Commercial/Industrial

One of the first questions asked was which potential sources of phosphorus were most feasible to quantify. The Missoula Wastewater Facilities Plan Update (1998) indicated that approximately 60% of the phosphorus inflow to the Missoula plant originated from single- and multi-family residential units, and 40% of the phosphorus load originated in commercial/government, restaurant, hospital and other sources. Due to the complexity and variability of the commercial sector, and the fact that it provides less than half the total phosphorus load in Missoula, it was decided to concentrate the study on the phosphorus contribution of residential wastewater users.

ii) Choice of Location:

The first shelf surveys of products were done in Missoula, because it is the commercial center for all Missoula County and parts of Ravalli, Mineral and other surrounding counties. Once the process of designing the telephone survey began, it was decided to do a pilot study in a small community to test the methodology, as Missoula's 18,000 residential wastewater connections implied a large, expensive survey. The University of Montana's Center for Rural Livability suggested that Lolo, Montana, a small community eight miles south of Missoula, would make a good site.

Lolo has an activated sludge-type wastewater treatment plant discharging into the Bitterroot River upstream of Missoula. The plant has 760 sewer connections, of which approximately 680 are residential (D. Harmon, 2001). Discussions between the University of Montana, the VNRP Coordinator, and civic leaders in Lolo indicated that the telephone survey of dishwasher detergent use would be an appropriate project which would complement other efforts to address water quality in the community.

iii) Assumptions:

The project is based on a number of assumptions, including:

*It is feasible to estimate residential dishwasher detergent use from a telephone survey.

*The survey provides a representative sample of Lolo sewer district customers.

*Phosphorus contained in dishwasher detergent is conserved as it passes through wastewater collection system and arrives at the wastewater treatment plant.

iv) Methodology:

a) Shelf Survey of Products

The shelf survey of automatic dishwasher detergent products was conducted by University of Montana student volunteers led by Catie Burnside, in fall, 2000. Eleven major supermarkets, including Safeway, Albertson's, Walmart, Rosauer's, CostCo, Target, Orange Street Food Farm, Bi-Lo, K-mart, Good Food Store and Tidyman's in Missoula were surveyed. All automatic dishwasher detergent brands in each store were recorded, as were price per ounce and labeled phosphorus content (percentage) of each brand. All detergents were classified as: powders, tablets or gels. Brands which were phosphorus-free were duly noted.

b) Telephone Survey

The telephone survey was designed to sample Lolo, Montana, residents, determine if their residence was connected to sewer (as opposed to private septic systems), and then asked further questions about dishwasher use. Each respondent whose residence had sewer service sewer was asked if they had an automatic dishwasher, the class and brand of detergent which they use, and the frequency of dishwasher operation. This sample then was extrapolated to the entire population of Lolo residential wastewater customers.

The actual implementation of the telephone survey was done with the assistance of Kathy Schaub of the University of Montana Foundation, who generously provided access to the Foundation's computerized telephone bank on the University of Montana campus, and trained the project's volunteers in use of the phone bank. Over 300 homes in Lolo, Montana, were contacted on the evening of February, 8th, 2001, by a cadre of ten trained telephone volunteers, all of whom were University of Montana students.

***Sampling:**

Chuck Harris of the University of Montana Social Science Research Lab helped obtain a digitized listing of over one thousand residential telephone numbers in the Lolo, Montana, area code. This digitized phone list was then entered into the University of Montana Foundation's computerized telephone data base. The Foundation's custom computer program sampled telephone numbers randomly from the Lolo data base. Of the 306 homes contacted on the night of the survey, 91 which agreed to the survey were believed to be on Lolo Sewer, and 70 of those also had automatic dishwashers. This is the group from which the dishwasher detergent use data was generated.

***Survey Design:**

The telephone survey is a series of questions designed to determine if the residence is connected to Lolo's sewer system, if they had an automatic dishwasher, the brand and type of dishwasher detergent used, the number of times per week they operate the dishwasher, and whether they knew whether the product contained phosphorus. This information is tabulated in a spreadsheet to generate an estimated phosphorus load per week from each respondent who is a) connected to Lolo sewer and b) has an automatic dishwasher. Statistics can then be generated for homes with/without dishwashers,

frequency of use, form of detergent used (powder, tablet, gel), and total dosage of phosphorus used per week.

***Estimates and Sources of Error**

Several sources of error are inherent in this project. These include:

*Error in estimating proportion of residences with automatic dishwashers--- 91 Lolo residences were questioned about dishwashers out of a total population of approximately 680 residences on sewer.

*Error in estimating frequency of dishwasher use—this is based on the subjective estimates of the respondents.

*Error in estimating quantity of detergent used per machine cycle—quantity of detergent used was estimated by the project personnel in their home dishwashers.

*Error in estimating concentration of phosphorus in detergent for respondents who did not know the brand of detergent used—the shelf survey provided average phosphorus content for each form (powder, gel, tablets) of detergent, which was applied when respondents did not know their brand.

We believe these errors have been minimized, within the constraints of time and effort available to this project, by the sampling procedure and by our methodology.

III) Results:

i) Shelf Survey Results:

The shelf survey of automatic dishwasher detergents found 17 brands of powders, 13 brands of gels, and seven brands of tablets available in 11 major Missoula supermarkets. Of these products, three powders, two gels, and one tablet form were zero phosphorus. The zero-phosphate detergents were only available in three Missoula supermarkets---Bi-Lo, Orange Street Food Farm and Good Food Store. A list of all surveyed brand name detergents with % phosphorous content, *phosphorus* content *in grams per tablespoon*, and price per ounce is found in Appendix 1. A listing of stores and product prices per store is also included in that Appendix.

The mean P content for powders which use phosphorus was 6.87 percent, or 0.9687 grams per tablespoon, and the mean P content for gels which use phosphorus was 4.02 percent or 0.562 grams per tablespoon. The mean P content for tablets which use phosphorus is 8.6 percent, and is measured on a per tablet basis as 1.715 grams per tablet. Therefore, gel is the form of detergent averaging the least amount of phosphorus per tablespoon.

Other than the zero phosphorus brands, the range of phosphorus content is not particularly great in any form of detergent. For example, 14 brands of powdered detergents ranged from 5.6 percent to 8.6 percent phosphorus, eleven brands of gel ranged from 1.6 percent to 4.9percent phosphorus (although 10 brands contained from 4.0percent to 4.9 percent phosphorus), and six brands of tablets ranged from 8.48 to 8.7 percent phosphorus.

As can be seen in Table 1, the price of phosphorus-free dishwasher detergents tends to be substantially higher than the price of the high-phosphorus brands. There are some small exceptions to this trend (e.g., Seventh Generation Powder averages $0.088/oz. versus the $0.059 to $0.079/oz. price of the popular Cascade brands; and the Palmolive gel with only 1.6% phosphorus which is average-priced for gels). But in general, the zero-phosphorus brands tend be less widely available and more expensive than other brands. This is probably due to low demand, and the fact that zero-phosphorus detergents are made by small, specialty companies, not the industry leaders.

TABLE 1: Mean P Content and Mean Prices of Dishwasher Detergents in Shelf Survey

	High Phosphorus Detergents			**Zero Phosphorus Detergents**		
FORM:	**N brands**	**% P**	**Price($/oz.)**	**N brands**	**% P**	**Price ($/oz.)**
Powders	14	6.87	0.048	3	0	0.138
Gels	11	4.02	0.056	2	0	0.104
Tablets	6	8.6	0.223	1	0	0.31

ii) Telephone Survey Results:

The telephone survey contacted 306 residences in Lolo, Montana. Of this total, 84 were connected to the sewer system, 10 didn't know, 87 were not connected (on private septic systems), and the remainder refused the survey, or did not answer the phone. Of the total of 84 definitely on sewer, and the 10 who didn't know, 91 complete surveys were done. Of this group of 91 complete surveys, 70 reported to have dishwashers, and therefore were the surveys from which dishwasher use and detergent use data were generated **.**

a) Percentage of Residences with Dishwashers

As stated, of the 91 complete surveys, 70 respondents had automatic dishwashers, yielding the conclusion that 77% of the population connected to the Lolo public sewer has dishwashers. An accurate estimate of this "percentage of population using dishwashers" is critical to any estimate of phosphorus load from this source. Using descriptive statistics a confidence interval can be constructed for the percentage of people who have a dishwasher, out of the entire population sampled (680 residences on Lolo sewer). A 95% confidence interval for this estimate is from 68.1%-85.6%.. The equation used to create this confidence interval for a finite population is:

$$\hat{p} \pm z^* \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \sqrt{\frac{N-n}{N-1}}$$

Where N=680 total residents that are hooked to the Lolo Sewer, n=91 residents sampled on Lolo Sewer, p=70 proportion of residents with a dishwasher, z=1.96 value to construct a 95% confidence interval.

Table 2: Telephone Survey Results: Residences in Lolo, MT on Sewer, and with Dishwashers

Percentage on City Sewer			
Results	**Count**	**Percent**	
Connected	84	27.45%	
Not Connected	87	28.43%	
Didn't Know	10	3.27%	
Refused Survey	49	16.01%	
No Answer	47	15.36%	
Answering Machine	29	9.48%	
Total	306	100.00%	
Percentage with Automatic Dishwasher			
Results	**Count**	**Percent**	
Yes	70	76.92%	
No	21	23.08%	
Total	91	100.00%	
Total Calls Made	306		
Total connected to sewer with dishwasher			70

b) Dishwasher and Detergent Use

The completed surveys were analyzed to reveal residential dishwasher use as a weekly average (see Appendix 2). The average dishwasher use was 3.67 times per week, and ranged from one to nine times per week.

To calculate phosphorus use per week, a phosphorus content was assigned to the preferred detergent of each of the 70 respondents. Then that respondents' phosphorus use was estimated using his data on dishwasher use and type of detergent, based on the following equation:

*dishwasher use per week (times per week the dishwasher was run) * tablespoons of detergent used per wash * grams per tablespoon of phosphorus for detergent specified = total grams P used per week.*

Several automatic dishwashers were investigated to test the amount of detergents the cups would hold. In dishwashers tested, if both cups are filled (pre-rinse cup and the time-released cup) approximately 4 tablespoons of detergent are used. However, it is reasonable to assume not every user fills both cups. If just one cup (the time-release) was filled it amounted to 2.5 to 3 tablespoons. Therefore, for the weekly use calculation we assumed 3 tablespoons were used per wash.

Question 5 of the telephone survey (telephone survey can be found in the Appendix 2) asked residents for a brand preference. Of the 70 residents sampled, 25 did not specify a

brand preference. Question 6 of the survey then asked for a brand form preference between a powder, gel, or tablet. If a resident did not have a brand preference the mean P content for the specific form of detergent they use was applied to their P use calculation.

c) Phosphorus Use per Week

The mean estimated phosphorus use per week is 10.98 grams/residence, and the median is 10.5 grams/week. Using Descriptive Statistics on SPSS software the standard deviation is 7.21 for the survey data. A confidence interval can also be constructed for our data. A 95% confidence interval is 9.26 -12.7 grams of phosphate used per week. Therefore, we are 95% sure that the mean number of grams of phosphate used per week is in the range of 9.26 – 12.7 grams. The formula used to create a confidence interval for a finite population is:

$$\bar{x} \pm t^* \quad \frac{s}{\sqrt{n}} \sqrt{\frac{N-n}{N-1}}$$

Where N=680 residents on Lolo Sewer, x=10.98 mean grams of phosphate used per week, t*=2 value to construct a 95% confidence interval, s=7.21 the standard deviation value.

Possible errors in our results include a possibly non-random sample of the population surveyed, errors by respondents in estimating their dishwasher use, and the estimate of detergent use per wash. However, we believe the survey results generate a mean phosphorus use per week estimate with an acceptable confidence interval.

IV) Analysis and Discussion:

i) Analysis:

a) Phosphorus Load from Dishwasher Detergent at Lolo WWTP:

The survey identified 91 households which were connected to Lolo sewer, or were not sure, and of those 70 households, or 77 percent, had automatic dishwashers. Applying this proportion of dishwasher ownership to the estimated 680 residential households on Lolo, sewer, we estimate 524 homes with automatic dishwashers. The dishwasher detergent phosphorus use data have a mean of 10.98 grams/week and a median of 10.50 grams/week. Therefore the mean is taken to be a good estimate of weekly phosphorus use.

Multiplying 524 homes x 10.98 grams/week x 52 weeks/year = **299,183 grams/year P**

This is equivalent to 299.2 kilograms/year or **659.7 lbs/year of detergent Phosphorus**

Or……..1.81 lb.P/day for Lolo, or……0.0034 lb./day/residence with dishwasher

b) Comparison to the Actual Phosphorus Load: Lolo

Lolo, Montana's wastewater treatment plant had a Facilities Plan prepared in January, 2000, which includes an overview of its operation, status, and future needs. This Plan includes estimates of phosphorus in Lolo's wastewater influent of approximately 0.006 lb/person/day, a standard textbook value. Wastewater influent phosphorus analyses have never been done in Lolo. Multiplying by a total daily user population of 1813 persons (this includes both residential and commercial, and schools), the total inflow load of phosphorus is estimated at 11.559 lb P/day. Of this load 86% or 9.935 lb P/day is estimated to originate from residential users (D. Harmon, HDR Engineering, 2001).

Phosphorus load in Lolo's wastewater effluent has been measured, and is approximately 6.3 lb/day. Table 2 expresses the estimated influent load and actual measured effluent load on a daily and annual basis, based on Lolo's 200,000 gallons/day average flow.

Table 3 :Total Phosphorus in Lolo Wastewater Influent and Effluent compared to Estimated Dishwasher Detergent Load

Source:	Concentration (mg/L)	Daily Load (lb/day)	Load (kg/day)	Annual Load (kg/year)
Influent (est.)	6.5 mg/L	11.56 lb/day	5.24 kg/day	1,913.6 kg/year
Influent (est. residential only)	No data	9.94 lb/day	4.51 kg/day	1,645.4 kg/year
Effluent (measured)	3.75 mg/L	6.3 lb/day	2.86 kg/day	1,042.9 kg/year
Dishwasher Detergents	Not applicable	1.81 lb/day	0.82 kg/day	299.2 kg/year

Based on this data it is estimated that the 299.2 kilograms/year of phosphorus from dishwasher detergents is 15.6% of the total phosphorus load arriving at the Lolo wastewater treatment plant. However, it is very possible that this is an underestimate of the importance of dishwasher detergent phosphorus in the total load. This is because the 6.5mg/L inflow concentration estimate at Lolo is substantially higher than nearby Missoula's average of 5.2mg/L phosphorus measured in wastewater influent (Missoula Facilities Plan Update, 1999). The low concentration of phosphorus in Lolo's effluent (3.75 mg/L)) is additional evidence that the 6.5mg/L influent estimate may be high.

If we use Missoula's actual inflow concentration of 5.2mg/L P, the annual P load in Lolo goes down to 1530.9 kg/year, and the proportion of that load made up of residential dishwasher detergent phosphates goes to 19.5%. This may be closer to reality, but confirmation awaits thorough inflow phosphorus sampling at Lolo.* The proportion of *the residential phosphorus load* in Lolo which is based on dishwasher detergent phosphates is 18.2% even using the 6.5mg/L inflow concentration estimate.

*Initial inflow sampling in October, 2001, measured 6.05 mg/L total phosphorus at Lolo WWTP, yielding an estimate that dishwasher detergent phosphorus is about 16.8% of the total influent load.--ed

These estimates fall within the range of 8%-34% of wastewater inflow phosphorus load originating in dishwasher detergents reported in Massachusetts (Organization for the Assabet River, 2001). In order to improve these estimates, it is imperative to measure, rather than estimate, phosphorus concentrations in Lolo's wastewater inflow.

c) Applying this Data to other Areas

The Missoula Wastewater Facilities Plan Update estimates that there are 18,715 residential sewer connections in Missoula. If dishwasher ownership is similar to Lolo, then approximately 14,410 homes on sewer have dishwashers. If their dishwasher and detergent use patterns are similar to Lolo's (each residence uses 0.0034 lbs. P/day), then Missoula users would dump 49 lbs/day of phosphorus from residential dishwasher detergents into Missoula's wastewater inflow stream, or 15.5% of the total phosphorus inflow load of 317 lbs/day. It is likely that restaurant and hospital users also use phosphorus-based dishwasher detergents, making the proportion of total load from dishwasher detergent use substantially higher.

In order to arrive at a higher-confidence estimate of the proportion of total phosphorus reaching Missoula's wastewater treatment plant which originates from dishwasher detergents, it would be necessary to do a telephone survey similar to the one done in Lolo. It would also be advisable to survey restaurant and hospital use of these detergents, in order to better quantify this portion of the load in Missoula, which has a higher proportion of its total wastewater inflow arriving from commercial/government and restaurant sources than Lolo.

The proportional load estimate based on the Lolo survey may be appropriate for rough estimates in other small towns in western Montana, although each wastewater plant has some unique characteristics in its pollutant inflow loads.

ii) Discussion: Policy Options

a) Reasons to reduce phosphorus discharge

Automatic dishwashers are apparently a major contributor of phosphorus into wastewater treatment plants. The major form of phosphorus in dishwasher detergents is tripolyphosphate, which is readily available for biological activities. Since very few wastewater treatment plants in Montana have nutrient removal capabilities, the majority of phosphorus coming into the plant is discharged, usually to local streams and rivers.

Excess loading of phosphorus into streams, lakes or rivers can cause drastic changes in water quality, including reduction in dissolved oxygen supplies, major changes in algae species and associated macro-invertebrate communities, algae blooms and associated foam and odors. The Clark Fork River and Lake Pend Oreille ecosystem in western Montana and northern Idaho is certainly vulnerable to these effects of nutrient pollution; indeed portions of the upper and middle Clark Fork are already severely affected.

Although there are many sources of phosphorus in the Clark Fork watershed, point sources, especially municipal wastewater treatment plants are the source for about one-half the dissolved phosphorus in the river (Ingman, 1992). Therefore, any significant reduction in phosphorus supplied to wastewater plants could reduce the total phosphorus discharged to the Clark Fork River and Bitterroot River in a meaningful way. In addition, reductions of phosphorus discharged from municipal wastewater plants may soon be required by TMDLs and or in-stream nutrient standards to be established by the Montana or Idaho Departments of Environmental Quality.

b) Feasibility of Using Alternative Dishwasher Detergents

Zero-phosphate automatic dishwasher detergents are available, and, at least according to the subjective experience of these investigators, appear to work quite satisfactorily to clean dishes, even with moderately hard groundwater as a source of tap water. However, availability and price are two factors currently mitigating against their wider use.

*Availability

Currently, zero phosphorus detergents for automatic dishwashers are available in Missoula, but their availability is limited to certain stores. Only three major Missoula supermarkets carry any zero-phosphorus products, and no zero-phosphorus products were located at the supermarket in Lolo. In certain respects, this situation is to be expected, as few people are aware of the potential impacts of dishwasher detergent phosphorus on river ecosystems. It is possible that greater demand, based on education, would stimulate retailers to provide more options for consumers.

*Prices

The significantly higher prices of zero-phosphate detergents may be a deterrent to some consumers who would opt to use these products for environmental reasons. Again, this situation may simply be one of supply-and-demand. The larger manufacturers are not supplying zero-phosphorus detergents; rather, it is small, specialty manufacturers who are currently providing these products. Given the low quantities of product being shipped, the unit costs of production and transport are probably significantly higher than the regular detergents. It is not known whether the alternative water-softening agents used in zero-phosphate are significantly more expensive ingredients than tripolyphosphates.

c) Education vs. Regulation of Phosphorus-Based Detergents

Relatively few residents of Lolo know whether their dishwasher detergents contain phosphorus, and many do not know of the pollution hazard phosphorus poses to rivers and lakes. In public meetings around the basin, the VNRP Coordinator has noted that citizens are generally very eager for information about how they can make a positive contribution to water pollution control.

The question of phosphorus in dishwasher detergents is usually new to people, even people who are particularly concerned about water quality issues. Therefore, it is likely that substantial education is needed to help citizens understand the role of dishwasher detergent phosphorus in water quality.

A substantial organizing and political effort was involved in passing a ban on the sale of laundry detergents containing phosphorus in Missoula in 1989. The process of establishing a similar ban was confrontational, and very political in Sandpoint, Idaho. Several smaller towns in Montana also passed their own bans. Among professionals involved in water quality it is assumed that the result of the ban in Missoula, a 30% reduction in phosphorus content of wastewater inflow, was substantive. The question remains whether a further 15-20% reduction in phosphorus load would be seen as worth the effort of organizing the necessary political support.

In order for behavior to change, whether voluntarily or through regulation, there needs to be both a strong educational effort, and real opportunities for people to purchase and use zero-phosphorus or low-phosphorus dishwasher detergents at a reasonable cost.

d) Residential vs. Commercial/Industrial Use

In Lolo, Montana, it is estimated that over 85% of the phosphorus load to wastewater is from private residential sewer users. In this case, it is clear that educational and political efforts to reduce phosphorus use should concentrate on residential sewer customers. In the case of Missoula, approximately 40% of the total phosphorus load originates from commercial, government, medical and school connections. Therefore, in Missoula it is important to further investigate the use of automatic dishwasher detergent phosphorus with these commercial and government establishments in order to better understand the origin of total phosphorus load.

It is probable that the commercial-scale dishwashers used in schools, hospitals and restaurants use processes and products which differ substantially from those used in residential dishwashers. The phosphorus content of those products would need to be investigated with wholesalers or directly with the end-user to generate good data.

Should Missoula decide to further investigate the origin of its phosphorus inflow load, it is recommended to use experienced social scientists with access to telephone survey infrastructure for residential use surveys. The Lolo pilot study can serve as a survey model. Investigation of phosphorus detergent use at commercial and government use would require custom-designed surveys.

V) Conclusions and Recommendations:

1) Phosphate Content in Dishwasher Detergents:

Automatic dishwasher detergents generally have a high phosphorus content, depending on the form of the detergent. In Missoula, available brands of powdered detergents average 6.87 percent phosphorus, gels average 4.02 percent phosphorus and tablets average 8.6 percent phosphorus. This is approximately the phosphorus content of houseplant fertilizers like Miracle-Gro. However, zero-phosphorus detergents are now available in some supermarkets in Missoula.

2) Availability and Price of Zero-Phosphorus Detergents:

Zero-phosphorus dishwasher detergents manufactured by smaller specialty companies are available in three out of eleven major supermarkets in Missoula, but prices per ounce for these products tend to be significantly higher than high-phosphorus brands.

3) Dishwasher Ownership and Use in Sewered Areas:

Dishwasher detergent phosphorus is transported in wastewater to municipal wastewater treatment plants in all sewered areas. A telephone survey in Lolo, Montana, revealed that 77% of residences reported owning an automatic dishwasher. They used this dishwasher an average of 3.67 times per week.

4) Phosphate Loads from Dishwashers:

A telephone questionnaire with 70 respondents in Lolo, Montana, yielded an estimate of 10.98 grams/ week of dishwasher detergent phosphorus used in every residence which owns a dishwasher (0.0034 lb/day P/residence). This phosphorus load is equivalent to 1.8 lbs/day of soluble phosphorus arriving at the Lolo Wastewater Treatment plant, or 15.6% of the total phosphorus load arriving at the plant. Since the plant inflow load is only an estimate, and is significantly higher than Missoula's actual inflow load (per person), it is likely that measurements of Lolo's inflow phosphorus load would reveal that the percentage of load originating in residential dishwashers is signficantly higher than 15%.

5) Options for Communities:

Communities may wish to consider reduction of phosphorus inflow to their municipal wastewater plants from dishwasher detergents for several reasons: 1) phosphorus is a key nutrient responsible for water pollution in streams, rivers and lakes due to its tendency to cause algae blooms and degrade water quality; 2) state agencies are tightening regulations on nutrients discharged from wastewater plants, and new water quality standards now under development for phosphorus may force communities to adopt new measures; 3) nutrient removal from municipal wastewater by biological and chemical treatment processes is often expensive and requires major capital investments in infrastructure; 4) education of residents on the phosphorus issue, and voluntary or enforced reduction in its household use, may be a less expensive management option for some communities than changing wastewater treatment.

6) Need for more information:

Further investigation into the contribution of dishwasher detergent phosphorus to municipal wastewater loads is clearly necessary. This pilot project in Lolo, Montana, is intended to demonstrate some of the methods and results from a small-scale study of this problem. Larger communities in the Clark Fork-Pend Oreille watershed such as Missoula, Butte, or Sandpoint, may want to investigate the particular characteristics of residential and commercial dishwasher detergent use and its impact on their municipal wastewater. It is clear, however, that dishwasher detergents may be an important source of phosphorus in municipal wastewater.

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Appendix 1: Shelf Survey Results in Missoula

Appendix 2: Telephone Survey Results in Lolo, MT

Appendix 3: Phosphorus Use Spreadsheet Calculation, Lolo Pilot Study