TREATMENT OF WASTEWATER ON SURFACE-MINED LANDS IN SOUTHERN WEST VIRGINIA[1]

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Abstract. Treatment of wastewater by communities in southern West Virginia is limited by steep terrain, low population densities, and lack of wastewater treatment facilities. These communities and individual households generally must find alternative on-site solutions for wastewater treatment. Typical septic tank systems with accompanying soil drain fields for individual homes are not feasible because of the steeply sloping terrain and shallow soils. Surface mining by mountain top removal creates flat land and, through reclamation, replaces soil materials which may be suitable for wastewater disposal and treatment. A field study was conducted to evaluate two minesoils (Kaymine and Sewell minesoil series) in southern West Virginia as potential soil materials for treating wastewater. Monitoring wells were installed at 50- and 100-cm depths at both sites, and tapwater or wastewater was surface applied to 9 m^2 field plots with three replications per treatment. The Sewell minesoil did not allow wastewater to infiltrate at rates sufficient for surface application of wastewater. Both tapwater and wastewater ponded on the surface and, after several application attempts, no water was collected in the Sewell monitoring wells. At the Kaymine site, phosphorus in applied wastewater was reduced from 86 to 92% in wastewater collected from wells. Iron, aluminum and manganese were generally reduced by more than 60%. Biochemical oxygen demand (BOD) showed reductions of 76 to 98%, and total suspended solids (TSS) were decreased between 45 to 80%. Fecal coliform bacteria were not found in lower numbers in wells compared to applied wastewater during the Jul and Sep sampling dates, but did show a 44% reduction on the Dec date.

ADDITIONAL KEY WORDS: Minesoils, nitrates, phosphorus, postmining land use, reclamation.

Introduction

Many southern West Virginia communities and individual households lack wastewater treatment facilities. In 1980, less than 20% of the housing units in southern West Virginia had adequate wastewater treatment systems (U.S. Department of Commerce 1980). The mountainous topography, decreasing population, and low employment rate in the area restrict the development of large municipal wastewater collection and treatment facilities. Only small amounts of flat or nearly-level land are available along creeks and rivers in the area. These lands are flood prone and generally already occupied by houses or other industries. Therefore, these communities must find other means and/or other technologies for wastewater treatment.

As building contruction commences in the area for new homes or other commercial and service industries, on-site wastewater

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treatment systems should be considered since large-scale, municipal alternatives are not economically feasible at current population densities. The cost of conventional wastewater treatment facilities is two to four times more per household in rural regions than in more densely-populated areas (Kreissel 1977). Surface or subsurface application of wastewater to land is applicable to rural areas where large systems may not be constructed or feasible. The traditional method of individual household wastewater treatment generally involves the installation of a septic tank and accompanying soil drain field system. However in southern West Virginia, steeply sloping land and shallow soils make septic tank drain fields hard to install and, when installed, often fail yielding little or no wastewater treatment.

Large tracts of flat land are created by the mountain top removal method of surface coal mining, a method commonly used in southern West Virginia. During reclamation, the site is not regraded back to "approximate original contour" and flat areas are left. Many flat areas left on mountain tops after coal mining are used as airports, shopping centers, schools, and housing developments (Zipper and Skousen 1990). Since reclaimed mine lands are used for construction sites and since large wastewater treatment facilities are unlikely to be constructed, on-site wastewater treatment systems using minesoils on these flat, reclaimed lands should be evaluated relative to their ability to accept and treat wastewater. If such soils demonstrate sufficient treatment potential, then individual wastewater treatment facilities can be designed and installed.

Proper functioning of a land application treatment system is controlled by adequate design, proper construction, and suitable characteristics of the soil. The capability of soils to accept and treat wastewater is based on several site specific factors such as physical and chemical properties of soil, vegetation uptake rates, depth to water tables, groundwater quality constraints, and microbiological composition and activity in soils.

Five minesoil series were established in southern West Virginia through support of USDA-Soil Conservation Service (SCS), the West Virginia Agricultural and Forestry Experiment Station, and coal mine operators (Wolf 1988). These five minesoils were characterized and analyzed for specific land uses such as agricultural, forestry, and wildlife uses. However, interpretations for other important land uses such as recreation, building site development, and sanitary facilities have not been made.

Before wastewater is applied to minesoils on a commercial scale, baseline data should be generated from small wastewater demonstration projects and research. Selected physical and chemical properties of the minesoils such as infiltration, cation exchange capacity, permeability, hydraulic conductivity, and moisture retention must be evaluated to estimate the suitability of these soils for land application of wastewater. In addition, comparisons should be drawn between wastewater applied to minesoils and wastewater collected from soils at various depths in wells to determine differences in biochemical oxygen demand (BOD), fecal coliform bacteria, nitrates, and other parameters that pose a contamination hazard.

This study was initiated to collect baseline minesoil and water quality data from two southern West Virginia mountain top removal surface mines where wastewater was applied to minesoils. Our objectives were 1) to examine whether or not surface-applied wastewater infiltrates into minesoils, 2) to analyze both tapwater and wastewater applied to minesoils, and water collected from monitoring wells at two depths, and 3) to evaluate whether these minesoils have the potential to treat surface-applied wastewater.

Materials and Methods

Site Description

Kaymine (loamy-skeletal, mixed, acid, mesic Typic Udorthents) and Sewell (loamy-skeletal, mixed, nonacid, mesic Typic Udorthents) minesoil series were selected to evaluate their suitability to treat wastewater. Both series are common minesoils in southern West Virginia. The Kaymine site was located on Tom's Mountain, 3.5 km southeast of Welch, McDowell County, West Virginia. The Sewell site was located on Bluestone Mountain, 4 km northwest of Northfork, McDowell County, West Virginia. Table 1 provides a profile description of each minesoil series used in the study.

Experimental Procedure

A nearly level area of about 18m x 9m (162 m^2) was chosen on each site based on soil pit descriptions and soil mapping. Six plots measuring 3m x 3m were placed within each 162 m^2 area and three replications of two water treatments (tapwater and wastewater) were randomly assigned to each plot. Buffer areas between plots were employed in the plot design to restrict surface flow of water to adjacent plots. Two monitoring wells, constructed from 5-cm (2-in) PVC pipe, were installed at random locations in each plot at 50 and 100 cm depths. The wells were installed 10 months prior to the first application of wastewater or tapwater to the plots.

The municipal wastewater treatment plant in Princeton, West Virginia provided the tapwater and wastewater. Ten applications of both tapwater and wastewater were conducted at about 2-week intervals from June to December, 1992. Tapwater and wastewater were tanked to each site by truck, and water samples from each tank were taken immediately before application to the plots and put on ice until laboratory analysis were conducted later that day. Each water treatment was applied to randomly assigned field plots by a small sprinkler at about 2.0 cm/hr for 2 hrs (about 378 liters or 100 gal per plot). Approximately 300 ml of water were extracted from each monitoring well 24 hrs after the plots were sprayed. Water samples extracted from monitoring wells were also iced and analyzed the same day they were extracted. All tapwater and wastewater samples from tanks and water from wells were analyzed for pH (electrode), BOD (5-day incubation), fecal coliform bacteria (filtration method after 24 hrs), nitrate (Carby field test kit), total suspended solids (TSS), phosphorus (P), iron (Fe), aluminum (Al), and manganese (Mn) by the methods outlined in Clesceri et al. (1990). Data from only four of the 10 sampling dates (Jul, Sep, Oct, Dec) are presented in this paper.

Data were analyzed by ANOVA to determine significant differences at $p < 0.05$ between water treatments (tapwater and wastewater) at both 50 and 100 cm depths. Means found significantly different were separated by Duncan's multiple range comparison test. Water quality data from tanks (tapwater and wastewater) were used to calculate reductions of BOD, TSS, fecal coliforms, and elements from tank water vs water collected from monitoring wells.

Results and Discussion

Characteristics of tapwater vs wastewater before application (tank) were very different for all parameters (Tables 2 and 3). Nitrates in wastewater were about double the nitrates found in tapwater. Phosphorus, Fe, and Al concentrations in tank wastewater were 10 to 100 times higher than tank tapwater. About the same difference was found for TSS and BOD. No fecal coliform bacteria were found in tank tapwater vs millions of fecal coliform bacteria in tank wastewater.

At the Sewell minesoil site, the tapwater and wastewater did not infiltrate into the minesoil. The water simply puddled on the surface even when we constrained the water on the minesoil with lawn edging. After the fifth attempt at applying wastewater to this site and obtaining no water in our wells, we ceased application and determined that this particular minesoil on this site was unsuited for wastewater disposal and treatment. Bulk density of the Sewell surface horizon was 1.76 Mg m^{-3} vs 1.70 Mg m^{-3} for the Kaymine minesoil (Scott Hoover, West Virginia

Table 1. Profile descriptions for the Sewell and Kaymine minesoil series.

Sewell Series (loamy-skeletal, mixed, acid, mesic, Typic Udorthents)

Horizon	Depths	Description
A	0-7 cm;	Yellowish brown (10YR 5/6) silt loam; weak coarse granular structure; very friable; many very fine to medium roots; 5 percent rock fragments (80 percent sandstone and 20 siltstone); very strongly acid (pH 4.5); clear wavy boundary.
C1	7-40 cm;	Yellowish brown (10YR 5/8) channery loamy coarse sand; many medium and coarse brownish yellow (10YR 5/8) and strong brown (7.5YR 5/8) lithochromic mottles; massive; firm; few very fine roots; 25 percent rock fragments (50 percent sandstone and 50 percent siltstone); very strongly acid (pH 4.8); abrupt wavy boundary.
2C2	40-104+ cm;	Very dark gray (N 3/0) very channery loam; common medium strong brown (7.5YR 5/8) lithochromic mottles; massive; firm; 50 percent rock fragments (90 percent sandstone and 10 percent siltstone); neutral (pH 6.8).

Kaymine Series (loamy-skeletal, mixed, non-acid, mesic, Typic Udorthents)

Horizon	Depths	Description
A	0-13 cm;	Dark brown (10YR 3/3) silt loam; weak very fine to medium granular structure; very friable; many very fine and medium roots; 15 percent rock fragments (10 percent sandstone and 90 percent siltstone); neutral (pH 6.8); clear wavy boundary.
C1	13-35 cm;	Dark brown (10YR 3/3) very channery silt loam; common medium yellowish brown (10YR 5/6) lithochromic mottles; weak coarse granular structure; friable; common very fine to medium roots; 40 percent rock fragments (25 percent sandstone and 75 siltstone); moderately alkaline (pH 8.0); clear wavy boundary.
C2	35-78 cm;	Dark brown (7.5YR 3/2) very channery silt loam; common medium yellowish brown (10YR 5/6) and strong brown (7.5YR 5/6) lithochromic mottles; weak coarse granular structure; friable; common very fine to medium roots; 50 percent rock fragments (25 percent sandstone and 75 percent siltstone); moderately alkaline (pH 8.3); clear wavy boundary.
C3	78-135+ cm;	Very dark gray (N 2/0) very channery loam; common medium yellowish brown (10YR 5/6) lithochromic mottles; structureless massive; friable; few very fine roots; 45 percent rock fragments (70 percent sandstone and 30 siltstone); moderately alkaline (pH 8.2).

University, unpublished data), and both are within the bulk density ranges of other minesoils. Hoover (unpublished data) also assessed hydraulic conductivity of these two minesoils and found hydraulic conductivity of the Sewell minesoil to be 5.2 x 10^{-4} vs 3.6 x 10^{-2} for the Kaymine minesoil, a difference of more than 2 orders of magnitude. These hydraulic conductivity values help explain the wide difference in infiltration of water on these two sites.

At the Kaymine site, water infiltrated into the minesoil and also flowed into our monitoring wells. Water pH between treatments and depth were not different during the Jul and Sep sampling dates, but were different in Oct and Dec reflecting the pH of the applied water (Table 2).

Nitrate, surprisingly, showed no difference between tapwater and wastewater wells on the first sampling date but the reason probably related to the small difference in nitrates between the tank tapwater and tank wastewater on this date (Table 2). However, the water collected from wells in Sep and Oct were significantly different between tapwater and wastewater at both depths. In Dec, nitrates were not significantly different with depth and treatment, and were similar to nitrates in tapwater wells.

Phosphorus, Fe, Al, and Mn concentrations in tank wastewater before application were higher than those found in water from wastewater monitoring wells (Table 2). For example, P in tank wastewater was reduced from 86 to 92% compared to P in wastewater monitoring wells, while Fe was reduced from 68 to 88%. These elements probably were retained in the minesoil on cation exchange sites, and further minesoil analysis (currently ongoing) will help determine the minesoils potential for ion retention. Elements in monitoring well water at both depths showed few significant differences on these four sampling dates. However, most of the elements showed a trend of higher numbers in wastewater wells vs tapwater wells.

Wastewater flowing through minesoils and into monitoring wells showed BOD reductions of 92 to 96% on the Jul and Sep sampling dates, and 76 to 78% on the Oct and Dec sampling dates (Table 2). The difference between the two time periods could be due to decreased microbial activities during late fall and winter months vs summer months. TSS was reduced in tank wastewater vs monitoring well wastewater by 45% in Jul to 80% in Dec. TSS was increased in tapwater monitoring wells compared to tank tapwater due to the washing of soil particles downward with initial water applications. Installation of wells disturbed the soils, and the 10 month period between installation and water application probably did not allow the soils to settle. TSS concentrations in tapwater well water during Oct and Dec were lower than early applications as the soil particles stabilized with time.

Fecal coliform bacteria were found in tap and wastewater from all of the monitoring wells during the first two sampling dates (Table 3). This result concerned us and, upon examination, we soon realized that we were not flushing the water extraction tubes sufficiently causing contamination of our tapwater well samples with fecal coliform bacteria. With improved flushing and cleaning of tubes between water extraction from wells during the Oct and Dec sampling dates, much lower numbers of fecal coliforms were found in our tapwater wells.

In wastewater wells, slight reductions in fecal coliforms compared to tank wastewater were found in Jul (9%), Sep (6%), and Dec (44%). In Oct, an 10-fold increase of fecal coliforms in the 100-cm wastewater monitoring wells was found compared to the bacteria found in tank wastewater. This was probably due to residual bacteria from previous wastewater applications.

Table 2. Water pH and elemental composition of tapwater and wastewater before application to minesoils (tank), and in monitoring wells at 50 and 100 cm in depth.

			Monitoring Wells			
	Tank		50 cm		100 cm	
Sampling Date	Tap	Waste	Tap	Waste	Tap	Water
pH						
July	7.4	7.0	7.6 a[1]	7.5 a	7.5 a	7.3 a
Sept.	7.3	7.2	7.2 a	7.0 a	7.1 a	7.0 a
Oct.	7.7	6.7	7.7 a	6.9 b	7.1 b	6.9 b
Dec.	8.0	7.4	7.7 ab	7.6 ab	7.9 a	7.4 b
NO_3 (mg/l)						
July	10	17	13 a	20 a	16 a	15 a
Sept.	16	36	14 b	24 a	17 b	28 a
Oct.	11	19	15 b	27 a	18 b	28 a
Dec.	22	50	21 a	30 a	23 a	28 a
P (mg/l)						
July	0.08	2.78	.08 a	.23 a	.10 a	.20 a
Sept.	0.06	3.38	.04 a	.44 a	.23 a	.42 a
Oct.	0.05	3.26	.02 a	.48 a	.10 a	.24 a
Dec	0.24	3.77	.10 a	.51 a	.31 a	.48 a
Fe (mg/l)						
July	0.23	1.61	.32 a	.51 a	.29 a	.43 a
Sept.	0.01	2.43	.02 b	.25 a	.27 a	.28 a
Oct.	0.09	1.47	.09 a	.22 a	.13 a	.20 a
Dec.	0.07	1.86	.05 a	.27 a	.23 a	.24 a
Al mg/l)						
July	0.08	1.06	.52 a	.87 a	.92 a	.53 a
Sept.	0.02	1.92	.11 a	.18 a	.37 a	.11 a
Oct.	0.28	1.01	.29 a	.99 a	1.10 a	1.04 a
Dec.	0.10	2.10	.30 a	.60 a	.20 a	.40 a
Mn (mg/l)						
July	0.01	0.72	.02 a	.30 a	.07 a	.01 a
Sept.	0.01	0.76	.01 b	.10 ab	.15 a	.02 b
Oct.	0.01	0.63	.02 a	.20 a	.01 a	.03 a
Dec.	0.01	0.52	.01 b	.03 a	.01 b	.01 b

[1] Values within rows at each sampling date with the same letter are not significantly different at $P < 0.05$.

Table 3. Biochemical oxygen demand (BOD), total suspended solids (TSS), and fecal coliform bacteria in tapwater and wastewater before application to minesoils (Tanks), and in monitoring wells at 50 and 100 cm in depth.

			Monitoring Wells			
Sampling Date	Tank		50 cm		100 cm	
	Tap	Waste	Tap	Waste	Tap	Waste
			BOD (mg/l)			
July	1.4	136	4 a[1]	12 a	6 a	11 a
Sept.	3.7	202	8 a	9 a	8 a	5 a
Oct.	5.4	214	16 b	49 a	14 b	44 a
Dec.	3.3	204	2 b	48 a	5 b	44 a
			TSS (mg/l)			
July	8	73	29 a	48 a	40 a	40 a
Sept.	0	107	16 a	37 a	43 a	25 a
Oct.	12	113	23 a	28 a	25 a	35 a
Dec.	12	161	16 a	24 a	17 a	32 a
			Fecal Coliform (number/100ml)			
July	<1	5.8×10^6	1.7×10^5	3.7×10^6	1.5×10^5	5.3×10^6
Sept.	<1	8.3×10^6	7.0×10^2	4.8×10^6	2.2×10^3	7.8×10^6
Oct.	<1	3.4×10^5	53	2.2×10^6	<1	3.9×10^6
Dec.	<1	3.3×10^6	<1	1.6×10^6	2.3×10^2	2.1×10^6

[1] Values within rows at each sampling date with the same letter are not signficantly different at $p < 0.05$.

Summary and Conclusions

Treatment of wastewater by the Sewell minesoil in southern West Virginia was undetermined. This minesoil did not allow water to infiltrate and no water was collected in 50 and 100 cm monitoring wells. The Kaymine minesoil removed P, Fe, Al, and Mn (usually more than 60%) from tank wastewater applied to minesoils compared to wastewater collected from wells. TSS were reduced from 45 to 80%, while BOD was reduced from 76 to 96%. Fecal coliform bacteria were reduced up to 44% on the Dec sampling date. These results indicate that the Kaymine minesoil has adsorption capacities which would allow removal of some of these pollutants from surface-applied wastewater. Further testing, longer application periods, and application during all seasons should be conducted to determine if these minesoils will treat wastewater consistently throughout the year.

Literature Cited

Clesceri, L.S., A.E. Greenberg, and R.R. Trussell. 1990. Selected physical and chemical standard methods for students. Based on Standard Methods for the Examination of Water and Wastewater. 17th Edition. American Public Health Association, Washington, DC.

Kreissel, J.F. 1977. U.S. EPA response to PL 92-500: Relations to rural wastewater problems. pp 21-36. In: McClelland, N.I., Individual Onsite Wastewater Systems. Proc. Third National Conference, 1976. Ann Arbor Science Publishers, Ann Arbor, MI.

U.S. Department of Commerce. 1980. 1980 census of population and housing. Part 50-West Virginia, PHC80 S2-50, Counties and Selected Places. Washington, DC.

Wolf, B.L. 1988. Soil survey of Wyoming County, West Virginia. U.S. Department of Agriculture, Soil Conservation Service, Washington, DC.

Zipper, C.E., and J.G. Skousen. 1990. Income opportunities on reclaimed surface mine lands in central Appalachia. Green Lands 20(3): 20-23.