1999 International Ash Utilization Symposium, Center for Applied Energy Research, University of Kentucky, Paper #3.
http://www.flyash.info

A Field Evaluation of the Use of FBC Flyash for Barnyard Pavement

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Keywords: arsenic, water quality, heavy metals, animal health

ABSTRACT

Pavement of muddy barnyards benefits livestock health by keeping animal feet and udders dryer and cleaner. In spring 1995, fluidized bed combustion (FBC) flyash was installed as a pavement material for barnyards on a farm approximately 40 miles north of Harrisburg, PA. The flyash was transported dry to the site in pneumatic tank trucks and hydrated to approximately 35% using a transit concrete mixer. The depth of the flyash pavement was approximately 45 cm (18 in). Six suction lysimeters each were installed in the paved and unpaved soil control of the barnyard. Despite fracturing, the pavement remained a useable cattle feedlot area until the pavement was dismantled in spring 1997. Chemical analysis of leachate indicates that, except for As and Ni, concentrations of flyash-related contaminants in leachate collected beneath flyash-paved areas are not different than those collected from beneath the unpaved control area. The average As and Ni concentrations in leachate from the flyash-paved area were higher than that from the unpaved control area but were well below the USEPA maximum concentration for drinking water.

INTRODUCTION

Pavement of muddy barnyards would provide a benefit to livestock health by keeping animal feet and udders dryer and cleaner. Animals with clean, dry feet are less subject to hoof problems than those subjected to constant muddy conditions. However, the likely reduction in mastitis is an even greater benefit. Mastitis is a bacterial infection of the cow's udder and is a major animal health problem in the dairy industry, costing farmers tens of millions of dollars annually in lost production, veterinary expenses, and animal deaths. In addition, animals that do not have to travel muddy feedlots expend about 35% less energy walking. This means that paved cattle feedlots would result in lower feed costs to the farmer and less food equals less CO_2, methane, N, and P exported into the environment.

With the support of the U.S. Department of Energy (USDOE), and the assistance of Black River Co-Gen Partners, the Agricultural Research Service of the United States Department of Agriculture (USDA/ARS) evaluated barnyard paving with fluidized bed combustion (FBC) flyash. Because of the high alkalinity of the FBC flyashes, oxyanions such as As tend to be mobile and heavy metals tend to be immobile within unsolidified flyash.[1] However, the mobility of these elements encased in a solidified flyash under barnyard conditions is not known. The purpose of this was to see if FBC flyash could provide an inexpensive barnyard pavement that would alleviate muddy barnyard conditions without causing an unacceptable environmental risk due to the leaching of heavy metals or As from the flyash.

METHODS

The evaluation was located on a farm approximately 40 miles north of Harrisburg, PA (76º 35' W, 40º 42' N, 225 m elev.). Cattle were being fed year round on the site, causing the soil to be highly enriched with N and P through the deposition of cattle manure. Continuous and intense cattle trampling had destroyed the soil structure of the site.

In April 1995, a 16 m (53 ft) by 5 m (17 ft) section of the barnyard was paved with approximately 30 mt (33 t) of FBC flyash supplied by the Black River Co-Gen partners from the power plant located in Fort Drum, NY. This plant uses three Ahlstrom Pyroflow fluidized bed boilers to produce high-temperature and pressure steam for electricity generation and hot water for heating. Although the plant also burns anthracite coal and clean wood chips, this particular flyash was produced from burning bituminous coal with locally quarried limestone, giving the flyash a calcium carbonate equivalency of about 60%.

The flyash was transported dry to the site in pneumatic tank trucks and hydrated to approximately 35% in approximately 4.5 cu m (6 cu yd) batches using a transit concrete mixer. When poured from the mixer, the hydrated flyash had a consistency of concrete and solidified in a manner similar to that of concrete. The depth of the flyash pavement was approximately 45 cm (18 in).

In the next few days after paving, six suction lysimeters were installed just beneath the bottom of the flyash pavement (approximately 50-cm). This involved drilling a hole into the pavement, installing the lysimeter, and repacking the hole with additional hydrated flyash. Six suction lysimeters were also installed in an unpaved soil control area of the barnyard. Such lysimeters provide information on leachate composition from the paved and unpaved areas. The farm owner was then given use of both the paved and unpaved areas, which included the confining and feeding of cattle.

Sampling of the lysimeters began as soon as soil conditions were wet enough to allow percolation of water. Sampling continued into the spring of 1996 when frost shifting of the paved area fractured either the sampling pipes or the ceramic cup ends of the suction lysimeters, rendering the lysimeters useless. During sampling, water volume was recorded and water samples were analyzed for N, Ca, P, heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), and As by the Agricultural Analytical Services Laboratory of The Pennsylvania State University. The flyash was analyzed by the toxicity concentration leachate procedure (TCLP) and for total elemental concentration by REIC Laboratories (Beaver, WV) according to USEPA methods.

RESULTS

Analytical: Total elemental concentrations of As, P, and heavy metals in the flyash were all low, and the TCLP concentrations were below the detection limits (Table 1). As typical of FBC flyashes, Ca concentration was high and the only element with detectable TCLP concentrations.

Table 1. Elemental analysis of FBC flyash from Fort Drum, NY, used in feedlot pavement.

Element	TCLP	Total Metals
	mg l^{-1}	mg kg^{-1}
As	ND	41.5
Ca	3520	262000
Cd	ND	0.21
Cr	ND	33.2
Cu	ND	18.1
Ni	ND	24.8
P	ND	272
Pb	ND	7.15
Zn	ND	32.4

Physical: During the period between April 1995 and July 1996, the flyash pavement continued to hydrate, especially at the edge. As a result, the pavement began to fracture into a mixture of size fractions approximating that of coarse gravel. Also, the expansion of the hydration caused the edge of the flyash pavement to be raised about 15 to 20 cm (6 to 8 in). Despite the fracturing, the pavement remained a very useable cattle feed lot area until the pavement was dismantled in March 1997 for disposal in a landfill licensed to accept flyash. A standard sized backhoe was used to break the pavement into large pieces. During loading, these large pieces tended to disintegrate into smaller pieces. This indicates that although the pavement lasted for two years under the pressure of cattle, the pavement would probably not sustain machinery traffic, other than that of medium (50-70 hp) farm tractors or skid loaders.

Chemical: The leachate elemental concentration data are presented in Table 2. Average Ca was significantly higher in the leachate collected beneath the flyash-paved area than under the unpaved soil control area (Table 2). This would be expected because of the high Ca content of the flyash (Table 1). The Ni concentration in the leachate was greater than that beneath the unpaved soil area (Table 2). This was due to a large increase in Ni concentration in April and early May 1996. As the spring progressed, the Ni concentration in the leachate began to decline. At no time during the sampling period did these Ni concentrations approach the USEPA ambient water criterion of 0.632 mg l^{-1}. [2, 3]

Table 2. Mean concentrations and (standard errors)* of elements in leachate from flyash-paved barnyard and unpaved control area.

	Flyash-Paved Area	Unpaved Soil Control
Element	Mean(n=12)	Mean(n=31)
	-------------------mg l^{-1}-------------------	
As	0.015 (0.004)a†	0.008 (0.001)b
Ca	329.2 (27.3)a	243.8 (24.7)b
Cd	0.004 (0.0003)a	0.004 (0.0003)a
Cr	0.012 (0.001)a	0.015 (0.005)a
Cu	0.019 (0.004)a	0.037 (0.01)a
N	85.7 (38.1)a	6.00 (1.17)b
Ni	0.018 (0.004)a	0.011 (0.0005)b
P	1.536 (0.55)a	0.546 (0.05)b
Pb	0.020 (0‡)a	0.025 (0.003)a
Zn	0.035 (0.005)a	0.043 (0.006)a

*Standard errors calculated with all available data.
†Means in the same row followed by the same letter are not significantly different (P>0.05).
‡Standard error is zero because Pb was at or below detection level.

Neither Cd, Cu, Cr, Pb, nor Zn concentrations in the leachate showed a significant increase over those from the unpaved control area (Table 2). Also, none of the heavy metal concentrations in leachate from the flyash-paved or the unpaved control area were above the EPA drinking water standards.[2, 3]

Nitrogen and P concentrations in leachate from the paved area was substantially higher than those from the unpaved control area (Table 2). The source of N and P in this study was from excreta of the cattle being fed on top of the study areas. Our initial hypothesis was that the flyash pavement would attenuate the leaching of P and N and thus improve ground water quality. However, we found that the cattle preferred to congregate on the flyash-paved area, thereby increasing the N and P loading on this area. Consequently, P and N concentrations in the leachate collected from beneath the flyash-paved area were higher than those collected under the unpaved control area.

Arsenic concentration in the leachate from the flyash-paved area was higher than that from the unpaved control, and the difference was greatest at the end of the sampling period (Table 2). At the end of the sampling period, the As concentration of one leachate sample from the flyash-paved area slightly exceeded the EPA drinking water standard of 0.05 mg l^{-1}.[2, 3] However, the mean As concentration over the sampling period from the flyash-paved area was less than one-third of the EPA drinking water standard.[1, 2]

DISCUSSION

Chemical analysis of leachate indicates that, except for As and Ni, concentrations of flyash derived contaminants in leachate from flyash-paved areas are not different than those from beneath the unpaved control area. The average As and Ni concentrations in leachate from the flyash-paved area appear to be higher than that collected below the unpaved control area, but both were well below the USEPA maximum concentration for drinking water.

Although there were slightly elevated As and Ni levels in the leachate collected beneath the flyash-paved area, the effect of these levels on water quality are best evaluated on a whole farm basis. For example, the size of the paved area in this study (80 sq. m or 901 sq. ft) would represent only 0.02 percent of the area of a 40 ha (100-acre) farm. If one assumes an As concentration of 0.01 mg/l in leachate under soil on the farm not paved with flyash, then the As concentration of the leachate beneath a flyash-paved area would have to be 450 mg/l for the As concentration in the average leachate beneath the whole 40 ha (100-acre) farm to be 0.05 mg/l. The 450 mg l^{-1} concentration is about 7,500 times greater than the maximum observed As concentration in leachate beneath the flyash-paved area in the study. Furthermore, the solubility of calcium-ortho-arsenate will only allow for a maximum concentration of about 25 mg As l^{-1}. Thus, the impact of the slightly elevated As concentration in the leachate beneath the flyash-paved area would have very little impact on ground water quality on a farm basis, even if the size of the flyash pavement was greatly increased in relation to the size of the farm or if the As concentration in the flyash was higher than that used in the study. From this data, it appears that FBC flyash of the composition used in this study can be used as an inexpensive barnyard pavement material without posing an undue risk to the environment.

ADOPTION

The cost of adoption of this technology is very favorable compared to bituminous or Portland concrete. The current cost of a flyash cattle feedlot is about $5.00 per cubic yard installed, about 1/10 the cost of Portland concrete.

Since 1996, this technology has been adopted in New York State and California. In California, the San Joaquin County Environmental Health Division has been collecting animal health data on dairy farms where flyash pavement has been installed.[4] Evidence collected so far indicates a sharp drop in the incidences of hairy foot wort, a viral hoof infection, and mastitis, a bacterial udder disease. The University of California-Davis Veterinary Medical School is doing additional work on the effect of flyash paving on animal health.

DISCLAIMER

Mention of a trade name or a supplier does not imply endorsement by the U.S. Department of Agriculture.

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