

sludge additions dramatically increased P uptake by sorghum.

Greenhouse data collected with three southwestern soils confirmed earlier reports that irradiated sewage sludge can be an effective source of Fe and Zn to sorghum growing in calcareous soils. Sludge and soluble extracts of the sludge were ineffective in improving the availability of added inorganic Fe to plants. Sludge was also identified as a potential source of available P to sorghum on the soils. This aspect of the work will be pursued since inorganic P fertilizers are quickly inactivated in many calcareous soils.

Thermoirradiation of sludge greatly facilitates the handling of sludge, destroys pathogens, and does not alter the availability of metals contained in the sludge.

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4. B. D. McCASLIN and V. R. LEE, *Proc. Int. Conf. Plt. Res.*, Texas Tech Univ., Lubbock, TX (1970).

#### 4. Sewage Solids as Supplemental Feed for Ruminants Grazing Rangeland Forage, G. Stanley Smith, H. E. Kiesling (NM State Univ), C. H. Herbel (USDA/SEA-Jornada Exptl Range-NM), E. E. Ray, Patricia Trujillo, Ruy Orcasberro (NM State Univ), J. S. Sivinski (Sandia Labs)

The solids in raw sewage represent a vast resource of nutrients that are potentially returnable to agriculture where constraints of pathogens and toxic chemicals are not prohibitive. Gamma irradiation from waste radionuclides such as  $^{137}\text{Cs}$  appears to be feasible as a means of pathogen reduction in large-scale operations.<sup>1,2</sup> Since 1975 New Mexico State University has evaluated dried, "radicized" solids from raw sewage (primary sludge) as a prospective supplemental feedstuff for ruminants (cattle, sheep) subsisting on poor-quality roughage feeds. Our published reports<sup>3-5</sup> and unpublished data support the view that products derived from raw sewage could provide substantial nutritive value to ruminant animals, without necessarily incurring intolerable risk to the animals or the human food chain, especially if such products are used only periodically in the maintenance of breeding herds and/or in the early "background" programs of young ruminants destined for slaughter much later.

Objectives of experiments reported here were to demonstrate under practical conditions the benefits from an experimental feed supplement (containing 62% dried, irradiated sewage solids) for gestating-lactating beef cows grazing dormant forage on semi-desert rangeland, and to assess, under extreme conditions, the accumulation of heavy metals and/or refractory organic compounds (toxicants) in tissues of cattle fed sewage solids for almost three months.

*Experiment 1:* During 1978 and 1979, 74 beef cows were managed as a single herd at the USDA Jornada Experimental Range, on semi-desert rangeland, near Las Cruces, New Mexico. One-third received no supplemental feed whereas one-third received conventional supplement (Cottonseed meal, CSM), and the other one-third received experimental supplement (RS#2, containing 62% sewage solids) for about three months in 1978 and two months in 1979 when cows were grazing dormant grasses while in late gestation and early lactation. Effects of supplemental feeding were measured mainly in terms of calf numbers and body weights at weaning and subsequent rebreeding by cows. Results are summarized in Table I. Samples of jugular blood, livers (biopsy sampled), and milk from these cows, taken at the end of the supplemental feeding period in each year, showed no difference ( $P > 0.05$ ) between supplementation treatment groups, in contents of Cd, Hg, or Pb.

*Experiment 2:* Dried, gamma-irradiated sewage solids were incorporated into an otherwise conventional diet for growing-finishing cattle and fed *ad libitum* for 84 days in feedlot, at which time representative cattle fed conventionally or experimentally were slaughtered. Others that had been fed experimental diet were changed to conventional diet and fed for 50 additional days and slaughtered. Samples of livers and kidneys from animals slaughtered after 84 days were analyzed by atomic absorption (emission) spectrophotometry for heavy metals and other elements. Results are summarized in Table II. Samples of adipose tissue (kidney fat) from representative animals slaughtered after 84 days and after 84 + 50 days were tested for 22 refractory organic compounds (pesticide residues) of which only 7 were detected, and none were at concentrations that exceed the range of values reported for beef cattle raised conventionally.

#### CONCLUSIONS

These results support our previous findings and tend to confirm the view that products derived from raw sewage (primary sludge) could be recycled as supplemental feeds for ruminants subsisting on poor-quality roughage feeds, at substantial nutritive benefits, without necessarily incurring undue risk from toxicity to the animals or accumulation of toxicants such as heavy metals or halogenated hydrocarbons (refractory organic compounds). Further research is required before feeding of sewage products could be recommended in practical livestock production.

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3. G. STANLEY SMITH et al., "Nutrient Usage and Heavy Metals Uptake by Sheep Fed Thermoradiated, Undigested Sewage Solids," in *Food, Fertilizer and Agricultural Residues*, Chap. 18, pp. 239-254, R. C. LOEHR, Ed., Ann Arbor Sci. Publ. Inc., Ann Arbor, MI (1977).
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5. G. STANLEY SMITH et al., "Prospective Usage of Sewage Solids as Feed for Cattle," in *Municipal Sludge Management: Impact of Industrial Toxic Materials on POTW Sludge*, pp. 190-200, Information Transfer, Inc., Silver Spring, MD (1979).

TABLE I

Breeding Performance of Beef Cows Given No Supplemental Feed (NONE) or Conventional Supplement (Cottonseed Meal, CSM) or Experimental Supplement (RS#2, Containing 62% Sewage Solids) During 1978 and 1979

ITEMS	SUPPLEMENTAL FEED		
	NONE	CSM	RS#2
Cows per group, 1978	24	25	25
Calves weaned, 1978	17	22	23
Cows per group, 1979	23	24	24
Calves weaned, 1979	14	19	17
Total Calves/Total Cows	31/47	41/49	40/49
"Calf Crop," %	66	84	82
Percentage change	--	+27	+24
Total Weight of Calves Weaned, kg/# Cows			
1978	3375/24	4283/25	4304/25
1979	2470/23	3070/24	2550/24
TOTAL	5845/47	7353/49	6854/49
Calf weight/cow in group, kg	125	150	140
Percentage Change	---	+20	+12
Cows Pregnant (11/30/79), %	61	87.5	87.5

TABLE II

Element Content of Livers and Kidneys (Dry Basis) from Cattle Fed Conventionally or Experimentally (in which dried, gamma-irradiated sewage solids comprised about 12% of total diet for 84 days)

ELEMENTS	TISSUES							
	LIVERS <sup>a</sup>				KIDNEYS <sup>a</sup>			
	GROUPS				GROUPS			
	Conventional (n=4)		Experimental (n=5)		Conventional (n=4)		Experimental (n=5)	
	$\bar{x}$	ppm, dry basis (+s)	$\bar{x}$	ppm, dry basis (+s)	$\bar{x}$	ppm, dry basis (+s)	$\bar{x}$	ppm, dry basis (+s)
Ag	36.1	(7.8)	34.1	(5.3)	2.4	(.3)	2.8	(.7)
Ca	125	(43)	122	(19)	379	(44)	400	(61)
Cd	.20	(.10)	.14	(.07)	.35	(.07)	.53	(.23)
Cr	3.6	(3.5)	3.0	(2.6)	9.9	(4.4)	9.4	(1.8)
Cu	211	(54)	183	(43)	139	(18)	151	(32)
Fe	190	(39)	172	(37)	172	(49)	210	(45)
Mg	614	(61)	557	(37)	606	(85)	626	(128)
Mn	8.0	(1.2)	6.4	(.6)	3.2	(.4)	3.4	(.6)
Ni	1.2	(1.0)	.8	(.4)	4.6	(2.3)	4.2	(.6)
Pb	<.8		<.8		<.8		<.8	
Zn	115	(15)	95	(15)	50	(21)	60	(11)
Na, %	.212	(.016)	.171	(.023)	.263	(.061)	.254	(.069)
K, %	.913	(.020)	.898	(.053)	.806	(.099)	.855	(.139)
P, %	1.03	(.05)	1.01	(.05)	.77	(.12)	.79	(.14)

<sup>a</sup>Experimentals do not differ (P > .05) from Conventionals in regard to any of the elements measured.