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The Deterioration of Manures Under Semi-Arid Conditions

BY

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THE DETERIORATION OF MANURES UNDER SEMI-ARID CONDITIONS.

By W. P. Headden and Earl Douglass.

INTRODUCTION.

For many years prior to the introduction of the sugar beet as a commercial crop it was the practice of most Colorado farmers to throw away the manure made upon the farm. The land seemed to be inexhaustibly fertile and work spent in spreading manure upon the land was considered labor wasted. In the early years of our agricultural development, this was, to a certain degree, true. The soil gave bountiful crops year after year, and any additional fertility seemed to do more harm than good by increasing stems and leaves at the expense of grain. During these years the manure, much of it first-class sheep manure from sheep which had been fed upon corn and alfalfa, was dumped into the creek beds or sloughs, or left upon the ground, and the corrals were moved when the layer of manure became so thick that the sheep were likely to jump the fence.

Manure of More Importance than Formerly.

The growing of sugar beets and more intensive methods of farming have changed this, and in those districts in which there are sugar factories, the manure is now carefully saved and spread upon the land. More thought is given to saving the manure and to increasing the supply by fattening cattle or sheep on the farms, the value of the manure being now taken into account as part of the profits. There are still too many places in Colorado where the soil is being robbed, while the means of restoring, or at least partially restoring the fertility is going to waste in neglected manure heaps.

The question of the deterioration of manures under our Colorado conditions is important for the reason that the high freight rates make it impracticable for the western farmer to use the commercial fertilizers which are in common use in sections nearer the great distributing centers, the sea ports and packing houses. In the west, very little attention has been paid either to the subject of fertilizers or barnyard manures and, so far as we know, no analytical data are at hand on the deterioration of manures under semi-arid conditions.

Fresh Manure Should Not be Used on Irrigated Soils.

Another question arises, when discussing the deterioration of manure, namely, the effect of fresh manure upon soils which are sometimes watered scarcely enough to produce a crop. In order to prevent waste of the elements of fertility under humid conditions, the general practice has been to use the manure as fresh as possible.

It probably seems improvident on the part of our farmers to have left the manure on the farm unused, but this was not wholly due to ignorance or to unwillingness to expend the labor necessary to apply it. The application of fresh manure to irrigated soils involves serious questions which are mentioned in this place merely to explain what must seem to most readers an irrational practice. Many inquiries among practical farmers brought out the fact that there are apparently good reasons for not applying fresh manure, namely, the manure does not rot and produces what is designated as "burning," by which they mean that manured land dries out quickly and the crop suffers. In fact the manure sometimes does more injury than good.

The Samples Studied.

The studies began in 1903 and 1904 during which time all the samples were collected and a large part of the analytical work finished. All the samples came from the vicinity of Fort Collins. Up to this time manures had not been used to any great extent except on small truck farms, lawns and gardens. Many car loads were shipped to Denver and it was a common sight in northern Colorado to see large piles of excellent corn-fed sheep manure left in the waste places of the farm to weather away. While the practice heretofore common among our farmers has been wasteful, the general result was to present an excellent opportunity for the study of the changes which had taken place in the manure due to the exposure to high winds, strong sunshine, and occasional heavy rains. There was no trouble at that time to get sheep or cattle manure of almost any age up to ten years and often even older, one lot being found which was twenty-seven years old. This was not the case with horse manure which, in our dry climate, fire-fangs badly. One instance came under our observation of a pile of horse manure taking fire spontaneously. For this reason practically no horse manure more than a year old can be found and that which has attained the age of a year and has lain in large heaps is simply a mass of dry, blackened stems, having very little value as a manure.

Waste of Liquid Manure.

Where so little attention is paid to the production of manure, no composting is done and the term "manure pile" simply means the pile of manure as it is thrown out of the barn or scraped out of the corrals. It generally contains only such bedding as was put into the stalls or corrals to keep the animals clean and not with the idea of absorbing the liquid manure or using straw as a part of the future fertilizer. No attempt whatever is made to use the liquid manure. If the barn can be so located that the urine runs away into a gutter or sewer, or if by means of a bed of sand the stall can be kept reasonably dry, the barn is that much better in the estimation of the average Colorado farmer. Even though the cultivation of the sugar beet has caused some improvement in our practice, still too little regard is paid to the saving of the urine, a very valuable, perhaps the most valuable portion of the manure. In the feeding corrals, this is not quite true for much of the urine is absorbed by the solid portion of the manure.

The Older Samples of Sheep Manures.

Some of the older samples came from corrals where sheep or cattle had been fed some previous year but the present owner had followed other pursuits, leaving the corral with its bed of manure untouched. Many of the samples were from piles from four to sixteen feet in height made by scraping out the corrals preparatory to another year's feeding. All the sheep manures, with four exceptions, were from sheep which had been fattened for market and had therefore been fed as much alfalfa as they would eat and a very heavy ration of corn.

Importance in Amount and Value.

The corrals are, in most cases, open pens without shelter except occasionally a board fence to keep off the cold winds. Since the average farmer who fattens lambs, feeds between one and two thousand head for a period of about 100 days, the amount of manure is considerable. In addition, the manure must be more than ordinarily rich in plant food since as much as 95 percent of the potash, phosphoric acid and nitrogen are voided in the dung and urine from sheep on full feed. From the foregoing brief facts it will be seen that we are here dealing with a very rich manure and one which under ordinary conditions would be subject to rapid deterioration.

The Cattle Manure Not so Easy to Obtain.

The cattle manure samples were more difficult to obtain as the industry of fattening cattle had not been so generally practiced. There are, therefore, few samples of manure from corrals where cattle had been fattened, but as this is a growing industry, more and more of it will be produced and its preservation will become correspondingly important.

Sampling.

In case the manure was in the corral, the loose material was scraped off the surface and at least three sections, each about eight inches square, were taken at different places. A portion of the sample was put into a glass vessel and sealed to prevent drying out; the rest was preserved with ordinary precautions.

If the manure was in a pile, an average depth was selected and a hole dug into the pile from the surface to the ground. When a smooth vertical surface was obtained, a slice about eight inches wide and three inches thick was cut from the top to the bottom and placed in a bag. A smaller sample was placed in a fruit jar and sealed. Forty-five of these samples were collected during 1903 and 1904 but no manure pile or corral was sampled unless a fairly accurate history of it could be obtained.

The determinations of free ammonia and moisture were made on the freshly taken and sealed samples. The samples in the bags were air-dried, ground and sampled. Bedding is not used in the corrals unless there is mud, which occurs rather seldom in Colorado. The winter of 1903 and 1904 was particularly open and dry and no bedding was used; for this reason the samples called fresh manure were free from straw, while the older samples were probably nearly so.

Loss of Dry Matter on Weathering.

From the foregoing preliminary remarks, it will be seen that our study will, for the most part, have to do with analyses of manures of different kinds and of various ages gathered at about the same time. There is, however, another factor which must be known before any sharp conclusions regarding deterioration of manures can be drawn, namely, the loss of dry matter through weathering. Any one who has observed a pile of manure in a barnyard knows that it gradually diminishes in bulk and changes its appearance until it is finally difficult to distinguish the manure from the soil itself.

AN EXPERIMENT WITH SHEEP MANURE.

To determine the amount of this loss, ten tons of sheep manure were obtained from a corral where lambs had been finished for market by the usual method. The manure had received no moisture during the whole time of accumulation and was tramped into a hard cake about six inches deep over the whole corral. No bedding had been used although some alfalfa stems from the feeding racks were found in the manure. The ten tons of manure were put into a crib with a board floor on March 2d, 1904, making a heap about 3½ to 4 feet deep. The aeration of the manure in hauling and placing in the crib, caused very active bacterial action which manifested itself in two or three days. To check the heating and settle the manure, it was wet down thoroughly but not enough to cause water to run through the pile.

Ammonia is Lost Rapidly.

A few days after this the smell of escaping ammonia was very strong, so strong that we tried to measure the ammonia by drawing air from the surface of the pile through normal sulfuric acid. A barrel was fitted with a stop cock in the bottom and used as an aspirator. Several flasks were filled with normal sulfuric acid and connected to a funnel, filled with cotton to prevent particles of manure from finding their way into the flasks. The funnel was simply laid on top of the manure pile and air drawn through the funnel and flasks by means of the barrel aspirator which held about 45 gallons of water or 6.015 cubic feet. When the water had all run out of the barrel, it was found that the flasks contained 0.0885 gram of ammonia.

An open dish of normal sulfuric acid with a surface of 67.2 square inches placed on top of the manure heap, absorbed 0.2606 gram of ammonia in 24 hours. This gives us some idea, vague though it may be, of the enormous loss of free ammonia. This fact has been observed over and over again and many ingenious ways have been used to show it, but each time we are astonished at the magnitude of this loss.

The Manure was Moistened.

Our object in this experiment was not to prevent all loss or even as much of it as is easily possible, but to determine the loss under ordinary conditions. The manure, however, was very dry and to prevent an extraordinary loss, it was thought best to wet it down thoroughly with the hose when first put into the crib. This was the only precaution used to prevent fire-fanging and was used only once.

On June 11, 1904, a hole was dug into the pile to see if any burning had taken place. There were some burned spots but the heavy rains had evidently kept the bacteria partially in check. There was a decided odor of ammonia and the manure was quite moist.

The First Weighing.

It was intended to weigh the manure at the end of the first year, but a long wet spell and work at the laboratory prevented until June 24th, 1905. On turning over the manure at this time, there was no odor of ammonia. The manure was well rotted and quite moist due to the recent rains. There must have been considerable loss from leaching as a rich brown liquid had oozed from the bottom of the crib and had run across the road in several places. A sample of each load was taken and after thoroughly mixing, two samples were drawn, one for the regular analysis and the other placed in a glass can and sealed for a determination of ammonia and moisture. The gross weight at this time was 20,595 pounds.

The Second Weighing.

The next weighing took place on May 18, 1906, and samples were taken as before. There had been heavy rains and the manure was again quite moist. There was no odor of ammonia.

Our Experiment is Stopped.

On March 20, 1907, when the time had come to reweigh the manure, it was found that by mistake a load of this manure had been taken out and used in the greenhouses. Samples were taken for analysis as before but the experiment was of course spoiled. It was hoped this study could be extended over a period of about five years. The results of the experiment are given in Table I.

Loss of Dry Matter as Determined by Other Investigators.

From many experiments conducted by Voelecker, with dung and litter, he concluded that from 30 to 60 percent of the original weight of the manure was lost in the course of six to twelve months time. This would indicate that our manure did not lose as rapidly as do those in climates where there is a heavier rainfall and consequently more leaching taking place. This fact is borne out by a comparison with other experiments as given by Storer in his work on Agriculture, and also by many experiments for short periods of time, generally less than a year. Taking these experiments as a whole, the loss in a year is about 45 to 50 percent, while the loss during this experiment was 32.5 percent in 15½ months, with a rainfall for that time of 26.18 inches, which is much more than the average for this locality.

Character of the Loss in Semi-Arid Climates.

Leaching occurs where the rainfall is heavy and washes away much soluble plant food, but helps to check the loss of ammonium compounds, while a dry climate prevents excessive leaching but destroys much nitrogen by volatilizing the ammonia.

Loss of Nitrogen.

Comparing the determinations of total nitrogen as they stand, without taking into account the loss in gross weight which occurred during the first year, there has been a loss of one-third of the total nitrogen, mostly in the form of free ammonia.

Taking into consideration the loss in weight of dry matter, there is a total or absolute loss of 48.6 percent of the total nitrogen during the first year—surely very startling figures to one who has not calculated the loss for oneself. The remaining manure is, however, more valuable under our conditions than the original larger quantity,

TABLE I.

DETERIORATION EXPERIMENT CALCULATED ON DRY MATTER.

Date	Weight in Pounds	Moisture Percent	Weight of Dry Matter	Loss Percent	Free Ammonia Percent	Total Nitrogen Percent
March 4, 1904	20,000	56.153	8,769	......	1.483	2.713
June 24, 1905	20,595	71.255	5,920	32.487	0.543	2.067
May 18, 1906	12,540	69.743	3,794	56.730	0.187	2.010
March 20, 1907	......	69.697	....	......	0.142	2.310

TABLE I, (Continued).

Date	Potassic Oxid Percent	Phosphoric Acid Percent	Soluble Ash Percent	Insoluble Ash Percent	Total Ash Percent	Sand and Silicic Acid Percent
March 4, 1904	3.892	1.172	6.180	16.756	22.936	8.222
June 24, 1905	5.999	1.004	8.890	22.030	30.920	9.239
May 18, 1906	6.012	1.102	7.468	28.560	36.028	10.678
March 20, 1907	6.189	1.072	7.695	32.040	39.735	12.082

because it can now be incorporated into the soil with advantage, and its humification may be completed in the soil while fresh manure may remain in the ground for years and produce objectionable results.

Loss in Two Years Found to be Less than Wolff Found in One Year.

The second year a further loss of 35.9 percent of dry matter occurred, making a total loss of 56.7 percent of the original dry matter in about two years. There seem to be very few experiments which extend over a period of greater length than one year, and we have consequently none with which to compare this loss. Wolff found that an 80-ton manure heap lost 65.5 percent of its dry matter in one year when exposed to wind and weather. This is much greater than our manure lost in two years. The total nitrogen decreased from 2.713 to 2.30 percent.

Loss of Nitrogen, Potash and Phosphoric Acid.

In order to compare the absolute losses to better advantage the results are calculated to pounds, and the losses given in percent. The original ten tons of manure contained 238.0 pounds of nitrogen, 341.3 pounds of potash and 102.8 pounds of phosphoric acid.

In June, 1905, when the original 8,769 pounds of dry matter had shrunk to 5,920 pounds, there were 122.2 pounds of total nitrogen, 355.1 pounds of potash and 59.44 pounds of phosphoric acid, or a loss of 48.64 percent of the nitrogen, and 42.17 percent of the phosphoric acid. The potash did not lose during the first year.

In May, 1906, the manure had further decreased in weight to 3,794 pounds of dry matter, and there were now present 76.27 pounds of nitrogen, 228.1 pounds of potash, and 41.81 pounds of phosphoric acid. This represents a total loss in two years of 67.95 percent of the nitrogen, 34.69 percent of the potash and 59.32 percent of the phosphoric acid.

In comparison with the losses from our manures, some instances of experiments at other Stations are here given, although it is a difficult matter to compare losses owing to the varying duration of the experiments and methods used.

Some Experiments at the New Jersey Station.

Dr. Voorhees in Bulletin 150 of the New Jersey Station, determined the loss sustained by 100-pound lots of cow manure when exposed to the weather in layers eight inches deep in a special form of galvanized iron box. From four experiments with mixed solid and liquid manure for an average of 82 days, there was a loss of 51.0 percent of nitrogen, 51.1 percent of phosphoric acid and 61.1 percent of potash. Another experiment by Dr. Voorhees* gives as the results with solid and liquid manure exposed from February 4 to June 15, a period of 131 days, a loss of 57 percent nitrogen, 62 percent phosphoric acid and 72 percent potash.

A Difference in the Losses is Found.

Both of these experiments at the New Jersey Station, while dealing with a different manure under more severe conditions, show very much larger losses in 82 days and 131 days, than our sheep manure exhibited in over one year. This is particularly true of the potash which lost more rapidly than either the nitrogen or phosphoric acid in both the above experiments while, in our experiment with sheep manure, no potash at all was lost during the first year, and only 34.69 percent at the end of the two years. This is certainly a very remarkable fact and shows the very different character of losses in semi-arid climates. With us the heaviest loss is in nitrogen, while the chief loss under humid conditions is potash. This simply indicates the different manner in which the loss takes place. In the humid climate the loss a manure sustains is caused largely by leaching which dissolves the soluble salts, the principal one of which is potash. On the other hand the chief loss in semi-arid climates is nitrogen because it is easily converted into ammonia and lost during dry weather, while the loss of potash is small on account of the smaller number of drenching rains.

A Series of Experiments at the Cornell Station.

Roberts and Wing exposed horse manure loosely piled in a box, surrounded by manure, for a period of six months. The losses were 36.2 percent of the nitrogen, 50.0 percent of the phosphoric acid and 58.8 percent potash. At the same time the foregoing experiment was being tried, a solid block of horse and cow manure, taken as it had been compacted by the trampling of the animals, was exposed to the weather and the losses recorded were 3.2 percent of the nitrogen, 4.7 percent of the phosphoric acid and 35.0 percent of the potash†.

In an experiment the following year a two-ton pile of horse manure lost 60 percent of its nitrogen, 47 percent of its phosphoric acid and 76 percent of the potash. A five-ton pile of cow manure presented an apparent exception to the above three experiments by giving losses amounting to 41 percent of the nitrogen, 19 percent of the phosphoric acid and 8 percent of the potash. Professor Rob-

*New Jersey Report of 1899.

† New York Cornell Station Bulletins Nos. 13 and 27.

erts says of this result, "It is worthy of note that in this experiment the loss of potash was very slight in comparison with the phosphoric acid and nitrogen; in all of our other experiments the heaviest loss has been potash."

Director Peter Collier at the Geneva Station, N. Y. Bul. No. 23, New Series, with a well packed heap of cow manure containing 3,298 pounds, found a loss of 60.6 percent of the potash in one year.

Other experimental proof might be given but in almost every case where the manure is really exposed to the weather and not taken care of, the heaviest loss in a humid climate is the potash.

No comparable experiments with sheep manure were found. The only experiments at our disposal in which sheep manure was used were those of Muntz and Giard as quoted by A. Herbert in an article in the Experiment Station Record. In these experiments the manure was exposed for a period of six months with a loss of 25.04 percent of dry matter, 11.44 percent of nitrogen, 19.15 percent of phosphoric acid and 21.5 percent of potash. It is not clear from the article whether the manure was cared for or not, but one would surmise that it was probably packed in heaps in pits and the leachings pumped back on the pile. If this surmise be true, our conditions are not comparable, and the small losses recorded would be easily accounted for even though the climate of France, where these experiments were conducted, is much more moist than ours.

THE TWENTY-THREE SAMPLES OF SHEEP MANURE.

We will now turn our attention to the samples of sheep manure which were collected during 1903 and 1904. As has already been stated the sheep, or rather lambs, were all fed for eastern markets on corn and alfalfa, with four exceptions, viz. Nos. 31, 32, 34 and 36, in which cases the sheep were pastured during the day and kept in corrals at night, the object being wool rather than the fat lambs. The winter of 1903-04 was an exceptionally favorable one for the collection of samples as there was almost no rainfall during that time and the samples can be compared without allowance being made for leaching.

A Standard Analysis of Sheep Manure.

In order to obtain a standard for comparison, a large number of analyses of sheep manures, most of which are given in Storer's work on Agriculture, were averaged and recalculated to a dry basis as follows:

Average Composition of Sheep Manure.

	Moisture Included Percent	Calculated on Dry Matter Percent
Moisture	66.40	
Dry Matter	33.60	
Ash	7.35	21.875
Potash	0.86	2.559
Phosphoric Acid	0.38	1.131
Total Nitrogen	0.74	2.203

Notes on Table II.

Nos. 14, 15, and 16 were manures made during the winter of 1904 and the sheep had either been shipped or were nearly ready for market.

No. 17 was also made during 1904. This is a sample of the ten-ton lot which was used for the deterioration experiment.

No. 18 lay in the open corral until October, 1903. Smelled strongly of ammonia.

No. 19 lay in an open corral.

No. 20 lay in pile since May 1903.

No. 21 lay in open corral until September, 1903. Pile 3½ feet high.

No. 22 pile three feet high.

No. 23 lay in the corral 1½ years, then was scraped into a pile 8 feet high. Inside of pile quite warm but did not seem to be fire-fanged.

No. 24 pile 3 feet high.

No. 25 pile 3½ feet high.

Nos. 26 and 27 from different farms. Piles four feet high. In piles two years.

No. 28 pile 2½feet high.

No. 29 two years in pile.

No. 30 pile 2½ feet high. Had been dumped near slough.

No. 31 sheep pastured on range during the day. Lay in an open corral.

No. 32 same as above except that it was under cover of a shed.

No. 33 had been put on top of other manure, but took only that which was four years old. Pile 5 feet high.

No. 34 pile 3½ feet high from same place as No. 31.

No. 35 had been hauled from the corral and dumped in a low, rather wet place.

No. 36 from a corral which had been used to shelter sheep which were pastured on the range. Manure about eight inches deep. Scraped off loose material before taking sample.

TABLE II.

PERCENTAGE COMPOSITION OF SHEEP MANURE, CALCULATED ON AIR-DRIED MANURE.

No.	Age Years	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
14	Fresh	61.748	38.252	7.454	11.878	19.332	3.666	4.975	1.145	35.310	1.757	3.107	1.797
15	Fresh	59.638	40.362	10.218	14.892	25.110	5.828	3.594	1.211	33.370	1.724	2.894	1.745
16	Fresh	55.642	44.358	8.012	18.586	26.598	11.160	5.200	0.812	31.180	1.888	3.011	1.854
17	Fresh	56.153	43.847	6.180	16.756	22.936	8.222	3.892	1.172	33.805	1.483	2.709	1.847
18	1	54.873	45.127	7.352	36.544	43.896	28.134	5.617	1.299	27.440	1.680	1.935	1.430
19	1	63.573	36.427	9.744	12.942	22.686	5.051	6.919	1.157	40.010	1.715	2.385	1.331
20	1	50.047	49.953	8.762	32.294	41.056	23.582	7.873	1.104	36.525	0.156	1.831	1.673
21	1	47.923	52.077	7.217	38.743	45.966	25.220	4.858	1.010	27.760	0.437	1.715	1.529
22	2	58.735	41.265	7.377	49.231	56.608	35.510	2.522	1.784	16.780	0.080	1.865	1.552
23	2	55.478	44.522	8.217	34.052	42.269	22.980	6.218	1.118	23.280	0.546	1.698	1.400
24	2	58.680	41.320	7.998	38.798	46.796	10.420	8.987	1.052	30.065	0.499	1.657	1.405
25	3	61.623	38.377	8.586	29.822	38.408	19.723	6.149	1.419	29.530	0.886	2.110	1.465
26	3	52.613	47.387	8.734	43.202	51.936	32.106	5.622	0.841	20.545	0.509	1.542	1.672
27	3	58.302	41.698	7.080	58.210	65.290	17.828	4.862	1.197	6.890	0.017	1.511	1.633
28	3	48.180	51.820	5.916	57.005	62.921	44.331	5.332	1.112	12.265	0.073	1.556	1.410
29	3	53.527	46.473	7.084	40.964	48.048	28.159	5.525	1.224	24.485	0.138	1.679	1.586
30	4	65.958	34.042	8.969	33.926	42.895	18.969	1.854	0.760	27.045	0.444	1.559	1.637
31	4	40.629	59.371	5.964	49.418	55.382	36.622	5.172	0.710	9.480	0.047	1.592	1.533
32	4	24.239	75.761	7.220	45.196	52.416	32.990	3.543	0.687	16.560	0.156	1.524	1.552
33	4	62.817	37.183	13.638	25.822	39.460	15.270	7.371	1.360	26.300	0.212	2.157	2.262?
34	5	32.543	67.456	4.512	71.240	75.752	56.802	3.974	0.689	3.205	0.022	1.179	1.217
35	5-6	64.304	35.696	5.832	40.418	46.250	24.679	6.317	1.833	22.920	0.759	1.786	1.678
36	27	34.426	65.574	5.526	64.382	69.658	37.250	3.843	0.718	4.565	0.028	1.185	1.152

Influence of Feed upon the Value of Manure.

Since the feed has a great deal to do with the amount of plant fertility in the manure, this should be taken into consideration when discussing different manures. Most of the manures used in the standard analysis were from sheep fed on hays, beets, pasture and a few on alfalfa, but almost none were from feeding pens where sheep had been fattened and had received as much as they would eat of corn and alfalfa. The alfalfa being very rich in nitrogen of course produces a manure rich in that element also. The difference in feed is forcibly illustrated in Table II. The potash, phosphoric acid and nitrogen drop decidedly in Nos. 31, 32, 34, and 36, which are from sheep pastured on native grasses. No. 30 is also low in these constituents, but for another reason. It had been dumped into a slough and had every chance to leach out. The sample was taken with the idea that it was as badly taken care of as any which came under observation.

Our Manures Lack Moisture.

The most noticeable difference between the standard analysis and the analyses as given in Table II is the low percentage of moisture. Not one is as high as the average analysis, and but few approach it. The average of the moisture determinations given in Table II is 53.115 percent which is 13.285 percent below that of the average analysis. These figures bring prominently before us the fact that our manures are comparatively very dry.

Soluble Ash.

In dividing the ash into soluble and insoluble ash, it was thought that an increase in the soluble portion would be found as the manure increased in age. We know that the insoluble organic matter is being constantly changed in form and much of it rendered soluble, but from a consideration of Table II, one is forced to the conclusion that the soluble ash is rather a constant quantity, not varying much from the average, 7.7 percent, except in a few instances. In the deterioration experiment we had for the soluble ash:

Fresh Manure	6.180 percent
First year	8.890 percent
Second year	7.468 percent
Third year	7.695 percent

These results are also very close together and seem to show that the manure can hold about 7 percent soluble matter, the rest being leached out.

Results for Potash Differ from those in Humid Climates.

In discussing the potash in the ten-ton lot of sheep manure, it was pointed out that there was no loss of potash during the first year although the manure lost 32 percent in weight in that time. The determinations given in Table II corroborate the fact that the potash accumulated during the first year and are repeated below in order that this fact may be clearly seen.

Percent of Potash in Fresh Manures	Percent of Potash in One-Year-Old Manures
4.98	5.62
3.59	6.92
5.20	7.87
3.89	4.86
Average 4.42	Average 6.32

The results of the deterioration experiment were 3.89 percent in the fresh and 6.00 percent in the one-year-old samples.

After the first year the potash does not seem to accumulate further, and taking into consideration the loss in weight which occurs each year, there is an absolute loss from that time on.

Phosphoric Acid.

The phosphoric acid determinations are very close together varying very little from 1.2 percent with a few exceptions due for the most part to a difference in feed.

An interesting question arises as to the loss of phosphoric acid and the accumulation of potash during the first year. From what we know of the phosphates, they are as soluble as the potash salts and the loss of phosphoric acid can therefore hardly be accounted for by the leaching which took place.

Crude Fiber.

The crude fiber is a determination not often made on samples of manure, and does not appear to be of much value here as a criterion of either the age or the value of the manure. In a general way, the crude fiber decreases with age, but there is a wide range in the figures without any apparent reason for it.

Nitrates.

The question of nitrates in the manure did not come up until most of the samples had been thrown away. However, the results obtained are of considerable interest as some of the samples gave abnormal amounts of nitrogen as nitrates. The following table gives the results obtained from those samples which had been kept.

Sample No.	Age	Percent N_2O_5
17	Fresh	None
17	1¼ years	0.465
17	3 years	0.752
15	Fresh	None
16	Fresh	Trace
18	1 year	0.371
21	1 year	0.108
25	3 years	0.287
26	3 years	1.610
27	3 years	0.821
31	4 years	0.188
33	4 years	2.151
35	5-6 years	0.093

The method used for these determinations was that of Schlosing and Grandeau as modified by Tieman and Schulze. Ten to twenty grams of manure were extracted with water and the filtrate and washings concentrated to a convenient volume from which point the above method, depending upon the reduction of nitric acid to nitrous oxid, was used. Precaution was taken in each case to absorb all carbonic acid by means of solid caustic soda in contact with the gas. To make sure that the gas was really NO, oxygen was admitted to the measuring tube a bubble at a time, and it was then found that all the gas oxidized readily and dissolved in water.

Voelecker* found only traces, not enough to determine quantitatively, of nitrates in either fresh or rotted manures. Holdefeiss also says that no nitrates are found when the manure is kept moist but that nitrates can form if the manure is covered with earth or is allowed to dry out. Holdefeiss found that as high as 8.5 percent of the nitrogen was present in a moist heap covered with earth, and an unmoistened heap carried as much as 18 percent of the nitrogen as nitrates.

The manure piles considered in this bulletin were, of course, not covered with earth and were not moistened except by the infrequent rains. The fresh manure contained none or doubtful traces of nitrates. In manure No. 17 there has been a steady increase in nitrogen as nitrates from none in the fresh manure to 8.5 percent of the nitrogen present as nitrates in the three-year-old manure. The other samples do not follow this increase with age, some being high and some very low in nitrates. Nor does the amount of nitrate present seem to be governed

*As given in Storer's Agriculture Vol. II. p. 319.

by the amount of moisture in the manure. The probability is that the conditions were right in some manures for the work of nitrifying bacteria. In other manures the nitrates had been washed away or nitrification had not taken place.

The three highest results, viz., Nos. 26, 27, and 33, have 27.13, 14.13 and 25.94 percent, respectively, of their nitrogen present as nitrates, which will be seen to be abnormally high as compared with Holdefeiss' figures.

The question might be raised whether nitrification had not proceeded in the sample cans in the laboratory. This was effectually settled in the case of No. 17. A determination of the nitrates in the three-year-old sample had been made in 1906 and a re-determination of nitrates in 1910 gave practically the same result. Air-drying the manure seems to stop most bacterial changes.

THE FREE AMMONIA.

The free ammonia in the manures which have been discussed in the foregoing pages offers a very interesting study not only because of the larger amount in fresh manures, but because it is the most easily lost of all the elements of fertility under our conditions. It has been pointed out that the principal loss from manures under humid conditions is potash but that the greatest loss in our climate is nitrogen. From the following discussion it will be seen that this loss occurs principally through a loss of free ammonia.

The bacterial changes taking place in the manure heap are very complex and not fully understood, but it is certain that among the first of these changes is the ammoniacal fermentation which first changes the nitrogen compounds of the liquid manure into ammonium salts, or allows the ammonia to escape into the air. Some of the ammonium salts are now oxidized to nitrites but are not changed into nitrates until all the ammonia has been dissipated or has combined to form neutral salts. The process is quickly completed in the liquid manure which contains organic nitrogen in a soluble form. The nitrogen in the solid portion is also attacked by ammonifying bacteria, but this change takes place slowly, which allows more time for the change into nitrates and nitrites. The great loss of ammonia from our sheep manures, however, must come from the comparatively swift change of large amounts of hippuric acid from the liquid manure into ammonia through the agency of uro-bacteria.

We know that most of this ammonia immediately combines to form ammonium carbonate, and being in this form it is peculiarly susceptible to changes in temperature and to the presence or absence of moisture. Now ammoniacal fermentation takes place most readily when the bacteria have a plentiful supply of air, warm sunshiny weather, and comparatively dry manure. It is easy to see, therefore, why manures under our conditions lose so much of their nitrogen. The bright, almost continuous sunshine and drying winds, are the two greatest agents tending to dissipate this valuable element of fertility. Another factor which is responsible for great loss of ammonia is the way in which our manures are cared for, viz., the practice of scraping the manure out of the corral into a loose pile. Admitting the air into the manure heap in this way both dries it out and supplies a plentiful amount of oxygen which gives just the right conditions for intense aerobic activity, especially when the cleaning of the corrals takes place in the summer time, as is usually the case. If the manure was compacted and moistened thoroughly, or put into pits and the leachings pumped back on the pile, as is the custom in France, the loss would be negligible in comparison with the good done by the slower and less destructive anaerobic fermentation.

What has just been stated regarding the loss of ammonia from manure which has been loosely piled up is well illustrated by four samples from Table II, viz., Nos. 18, 19, 20, and 21. These manures are all one year old, but had been treated in different ways by the farmers who owned them. Number 18 was scraped into a pile the fore part of November, a few days before the sample was taken. Number 19 lay untouched in an open corral. Number 20 had been scraped into a pile in May, and Number 21 early in September. Samples of these manures were collected in November and analyzed immediately with the following results:

No. 18 ---------------1.68 percent free ammonia.
No. 19 ---------------1.72 percent free ammonia.
No. 20 ---------------0.17 percent free ammonia.
No. 21 ---------------0.44 percent free ammonia.

While they are of the same age, we see that Nos. 20 and 21, which had been scraped into piles, had lost almost the whole of their free ammonia. Number 18, which had been placed in a pile a little while before the sample was taken, smelled very strongly of ammonia and was therefore losing ammonia rapidly at that time and probably dropped from 1.68 percent in the course of two or three months down to the level to which Nos. 20 and 21 had fallen in a like time. Turning now to No. 19, which lay in an open corral compacted by the trampling of the sheep during the feeding time, we find 1.72 percent, the same amount of free ammonia found in the fresh manures. The lack of air practically stopped the action of aerobic bacteria and anaerobic fermentation had proceeded slowly within the layer of manure.

An objection might be raised that the difference in content of free ammonia was the result of unequal bacterial activity, and that more ammonia had been formed in No. 19 than in the others, but a comparison of the determinations of total nitrogen in the thoroughly dried samples, shows that the ammonia had been formed in equal amounts in these manures, but had been lost before being changed into a form which could be better retained by the manure.

This can be seen to better advantage by repeating the figures given in Table II for these four manures.

	Total nitrogen in fresh samples.	Total nitrogen in air-dried manure.
No. 18	1.935	1.430
No. 19	2.385	1.331
No. 20	1.831	1.673
No. 21	1.715	1.529

It will be noticed that all four manures have nearly the same amount of nitrogen in the air-dried samples, and since the sheep were all fed alike, at the same time and in the same way, it would be reasonable to suppose that these manures had over two percent of total nitrogen as they lay in the corrals and it was only when they were scraped out and aerated that the ammonia was lost.

Another factor tending to preserve the ammonia in No. 19 was the larger amount of water present.

No. 18	54.87	percent moisture.
No. 19	63.57	percent moisture.
No. 20	50.05	percent moisture.
No. 21	47.92	percent moisture.

No. 19 had not lost its moisture because it had been left undisturbed in the corral, and this was not due to a favorable location. The corral in which it was found was on top of a hill with no shade of any kind. No. 18 probably had just as much or more moisture as it lay in the corral a few days before, but in scraping it up and hauling to the pile it had lost about 9 percent as we are justified in concluding from the fact that comparable samples from the same farm contained 62 and 63 percent moisture.

Table II shows how dependent the percentage of free ammonia, and to a slighter degree that of the total nitrogen, is upon the water content of the manure. The more moisture in the manure the more free ammonia and total nitrogen is present. There are three samples, Numbers 18, 25, and 33 which came from the same farm. They were on the north side of a row of thickly set cottonwoods and the moist condition was noticeable at the time of taking the samples. Their larger percentages of total nitrogen, 1.935, 2.110, 2.157, show the effects of the larger content of moisture which prevented a part of the loss of ammonia, or, which amounts to the same thing so far as the value of the manure is concerned, retarded ammonification, and allowed more time for the formation of ammonium salts. The moisture also helps check excessive heating, which dissipates much of the nitrogen as ammonia in a semi-arid climate.

Another prominent case in point is No. 35, with 64 percent moisture which, though five or six years old, has retained 0.759 percent free ammonia.

It will be noticed that the free ammonia amounts to about half the total nitrogen in the fresh manures and that there was a large loss on air-drying these samples. As we pass down the table to the older manures, this loss on drying becomes less until from No. 30 on there is scarcely any free ammonia, and practically no loss on air-drying, except in the case of No. 35 which was moist enough to retain 0.759 percent of free ammonia. This seems to indicate that at the end of about three years ammonification has entirely ceased, and the ammonium salts formed have either been lost or changed into nitrites and nitrates. It is probable that ammonification practically ceases long before this, especially when the manure has been disturbed and aerated.

The Loss of Ammonia in the Deterioration Experiment.

The "fresh" manure, or the manure as it was taken out of the corral, contained 1.48 percent of free ammonia, which makes 130 pounds in the ten tons of manure. At the end of 15 months there were but 32.2 pounds of ammonia. If no loss had occurred during this time our total nitrogen ought to be about the same in the sample when placed in the crib and again a year and a quarter afterwards, but we find that the total nitrogen has shrunken from 237.9 pounds in the ten tons to 122.4 pounds when sampled again, a loss of 115.5 pounds. We know that some leaching occurred during this time but it surely could not have been of much consequence when no potash was lost. The loss of nitrogen must, therefore, occur almost wholly through a loss of ammonia.

Furthermore, from a series of determinations of nitrates, as given elsewhere in this bulletin, there was present but 0.121 percent of the manure as nitrates at the end of 15 months. There might have been some nitrates present, but certainly not much of the ammonia had been converted into nitrates.

In all probability the greater portion of the work of ammonification had taken place and the 32 pounds of free ammonia obtained at the end of 15 months were simply ammonium salts awaiting nitrification. At the end of the second year there were but 7.1 pounds of ammonia, showing that ammonification had now almost entirely ceased, if, indeed, it had not done so sometime previously.

The further loss of 46.1 pounds of total nitrogen during the second year points to the fact that ammonia was still escaping, though much less rapidly than in the fresh manure.

Another fact responsible at times for large losses of nitrogen is the presence of denitrifying bacteria which set free elementary nitrogen.

CARBON AND HYDROGEN.

Elementary carbon and hydrogen determinations were also made on these samples of manure, the object being to find out to what extent the carbon accumulated in the manure as it grew older. Theoretically it would seem as though the amount of carbon would increase as the manure is changed by the bacteria with the formation of soluble salts and setting free of gases. Since the insoluble ash accumulates with the age of the manure, this factor must be eliminated in the results. The percentages of carbon and hydrogen are, therefore, re-calculated which gives a better basis for comparison.

The re-calculated results present a remarkable series. Far from being a variable quantity or showing any accumulation with age, the ratio of the carbon to the hydrogen is as constant a quantity as if the material were a series of lignite coal samples rather than manures. The average gives a ratio of 33.6 to 4.9. The breaking down of the cellulose with the liberation of carbon dioxide has kept pace with other kinds of fermentation leaving the same relative amounts of both carbon and hydrogen present in the manure.

TABLE III.

Carbon and Hydrogen in Sheep Manures.

The results are in percent of air-dried manure.

Sand and Silicic Acid Included				Sand and Silicic Acid Excluded	
No.	Age	Carbon	Hydrogen	Carbon	Hydrogen
14	Fresh	37.809	5.682	39.250	5.843
15	Fresh	33.110	5.021	35.160	5.332
16	Fresh	30.095	4.803	33.875	5.412
17	Fresh	29.011	4.803	31.610	5.331
18	1 year	24.712	3.649	34.385	5.078
19	1 year	34.521	5.276	36.358	5.557
20	1 year	25.130	3.575	32.884	4.678
21	1 year	25.695	3.668	34.722	4.905
22	2 years	23.623	3.110	36.630	4.823
23	2 years	27.291	3.792	35.434	4.924
24	2 years	25.942	3.560	28.950	3.974
25	3 years	28.686	4.069	35.734	5.069
26	3 years	22.580	3.092	33.258	4.554
28	3 years	16.910	2.276	30.376	4.089
29	3 years	25.398	3.443	35.344	4 792
30	4 years	28.680	3.776	35.394	4.660
31	4 years	22.450	3.195	35.423	5.041
32	4 years	25.215	3.483	37.630	5.198
33	4 years	27.624	3.968	32.602	4.683
34	5 years	12.600	1.609	29.169	3.725
35	5-6 yrs	25.471	3.590	33.816	4.766
36	27 years	12.748?	2.717	20.317?	4.431

THE CATTLE MANURES.

We will now turn our attention to the cow or cattle manures collected during the same winter as the sheep manures, but not presenting so continuous a series. To enable a better comparison, we give an average analysis which is obtained from about fifty analyses as given by Storer in his "Agriculture." Many of the analyses included in this average are of fresh manures, but this does not affect the results for they were not much higher in moisture than the old manures. This average represents manures as they are met with in moist climates.

Average Composition of Cow Manure in Percent.

	Moisture Included	Dry Matter Only
Moisture	74.66	
Dry Matter	25.34	
Ash	4.31	17.01
Potash	0.56	2.21
Phosphoric Acid	0.32	1.26
Total Nitrogen	0.57	2.24

TABLE IV.

PERCENTAGE COMPOSITION OF COW MANURES, CALCULATED ON AIR-DRIED MANURE.

No.	Age Yrs.	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
1	1	31.534	68.466	5.275	54.315	59.590	41.885	5.151	0.629	18.235	0.229	0.914	1.080
2	2	69.230	30.770	5.595	47.597	53.192	36.988	3.647	0.727	20.445	0.397	1.624	1.101
3	3	39.109	60.891	4.612	60.616	65.228	48.285	3.965	0.660	15.840	0.035	0.558	1.005
4	10	66.081	33.919	7.676	39.208	46.884	25.977	6.899	1.482	24.375	0.316	1.661	1.665
5	10-12	49.110	50.890	3.189	58.133	61.322	43.865	3.511	0.808	16.075	0.022	1.147	1.135
6	3	65.732	34.268	9.992	37.814	47.806	22.954	6.665	0.939	22.575	0.665	1.825	1.484
7	½	38.490	61.510	2.300	39.946	42.246	32.553	2.599	0.702	18.480	0.057	1.415	1.424
8	½	54.328	45.672	7.966	32.188	40.154	28.494	4.022	0.839	14.550	0.261	2.220	1.851
9	1	76.112	23.888	5.469	35.654	41.123	27.743	4.030	0.776	24.300	0.092	1.740	1.538
10	2	57.380	42.620	4.434	48.024	52.458	39.500	3.639	0.958	4.325	0.141	1.523	1.369
11	2-5	44.218	55.782	2.552	52.776	55.328	44.600	5.588	0.794	7.995	0.023	1.606	1.542
12	10	48.736	51.264	3.730	56.830	60.560	45.160	5.201	0.984	7.500	0.084	1.405	1.347
13	18	35.978	64.022	.....	......	72.344	64.651	5.396	0.687	2.685	0.015	0.941	1.014

Notes on Table IV.

No. 1. This manure was in a pile five feet high. The cattle were fed alfalfa hay.

No. 2. Manure was in corral one year and was then put in pile four feet high. The feed was alfalfa hay.

No. 3. This manure still lay on the ground in the corral. The feed was alfalfa hay.

No. 4. This manure was in a pile four feet high. The feed was alfalfa hay and corn.

No. 5. Only a small amount of this manure remained. The feed was corn, barley and alfalfa.

No. 6. This manure was in a pile four feet high. The feed was corn and alfalfa.

No. 7. This manure was from milk cows, pastured during the day on native mountain grasses. No grain fed.

No. 8. From milk cows fed as No. 7.

No. 9. This manure was in pile three and one-half feet high. The feed was alfalfa and timothy hays.

No. 10. This manure was made under cover of a shed, and had not been piled up. The feed was native, timothy and alfalfa hays.

No. 11. Same as above except that only native hay was used.

No. 12. This manure was undisturbed in a corral for two years and was then placed in a pile and remained there for eight years. The feed was native hay.

No. 13. This manure was from a pile which had weathered until it was but one and one-half feet high. The feed was native hay.

Moisture is Low in Cattle Manures.

A comparison of Table IV with the average analysis given shows a most striking difference in the moisture content, nor is this difference due to the inclusion of a number of fresh manure analyses in the standard analysis, for in an experiment conducted by the New York Station, Geneva Bul. No. 23, New Series, the moisture in the manure after one year's weathering is given as 75.18 percent. The average amount of water in the 13 manures given in Table IV is 52 percent or 22 percent less than in the average analysis. The cow manures are drier even than the sheep manures which had 13.3 percent less moisture than the standard analysis. Number 9, which has 76 percent moisture was from a pile under the eaves of a barn where it received the water from the roof during rainstorms.

There Was Some Difficulty With Sand.

The total ash is high compared with the average, but when the sand and silicic acid are subtracted, the results are very close to those of the standard analysis. One of the difficulties with a few of the older samples of the cow manures was the presence of large amounts of sand and gravel which had been blown or trampled into them. Literally a quart or two of gravel had to be picked out of some of the samples before anything in an analytical way could be done with them. For this reason the sand and silicic acid were carefully determined in the ash, although some of the silicic acid belongs to the ash of the manure as it was a constituent of the plants the animals fed upon.

The Soluble Portion is Nearly a Constant Quantity.

While discussing the soluble and insoluble ash in sheep manure, it was stated that the soluble ash did not increase with age, but remained near 7 percent. This is also the case with the cow manures, except that the soluble ash amounts to about 5 percent. This probably points to the fact that the manure can retain about that amount of soluble ash, the rest being lost through leaching. We know from many experiments, some of which have already been cited in connection with the discussion of sheep manure, that all manures lose rapidly in bulk and weight when exposed to the weather, and an increase in the ash content, soluble as well as insoluble, should take place, but we find that the soluble ash remains constant. The loss consists chiefly of soluble salts and liberated gases, such as carbon dioxide and nitrogen, caused by the action of micro-organisms. From the results given in Table IV, it would seem that almost the whole of these soluble salts are lost since the manure retains only about 5 percent no matter how old it is. This loss is principally due to leaching, for some of our rainfalls are heavy, and sometimes extend over a considerable period.

Solubility of the Nitrogen, Potash and Phosphoric Acid in Water.

It was so unusual to find the potash retained by the manure to a greater extent than the nitrogen, that 200 grams of manure No. 17 were extracted with water, and the potash and phosphoric acid determined in the extract.

After washing with water there remained 164.4 grams of manure making a loss in the extract of 17.8 percent. The nitrogen was determined in the residue and in the original sample, the former giving 1.817 percent and the latter 1.125 percent, a difference of 0.692 percent, which was the amount soluble in water. The phosphoric acid in the soluble portion amounted to 0.265 percent and the potash to 1.700 percent calculated on the air-dry manure. This shows conclusively that it was not because the potash was held as some insoluble salt in the manure but because there had not been enough rain to wash out the potash during the first year. The above figures represent a loss of 43.7 percent of the potash, 22.6 percent of the phosphoric acid and 38.0 percent of the nitrogen, which correspond closely to the results obtained under humid conditions.

Potash and Phosphoric Acid.

Since the potash salts and the phosphates are among the soluble salts, we find they are among those lost by leaching. It was pointed out that the phosphoric acid in the sheep manure was lost at about the same rate that leaching occurred. This seems to be the case here as the phosphoric acid determinations run very close together with the exception of No. 4, which is probably high on account of the heavy ration of corn and alfalfa these cattle received. The potash determinations vary to a greater extent than those of the phosphoric acid, but to what this is due is a question. The cattle manures are much more unsatisfactory than the sheep manures, because so many different combinations of hays and grains fed are represented. The rich feed gives a manure rich in plant food, and this difference sometimes persists after years of weathering. The phosphoric acid and nitrogen are less than results given in the standard analysis, while the potash is much higher. This again emphasizes what has been said regarding the loss of potash from sheep manure, and corroborates the statement that the heaviest loss under our conditions is not potash but nitrogen. The average of 13 potash determinations is 4.64 percent, more than twice the percentage in the standard analysis.

There is, of course, an absolute loss of potash as the manure loses in weight through weathering. This loss probably begins at about the same time it did in the sheep manure, namely, after the first year, and from that time on, like the phosphoric acid, it is lost at about the same rate as the manure loses in weight.

The Nitrogen.

The total nitrogen is lower than in the standard analysis. The average of Table IV is 1.43 percent, while the standard analysis gives 2.24 percent. The standard analysis is composed of very much younger manures than those in Table No. IV, and it will be noticed that the only manure in the table, No. 8, having an amount of total nitrogen equal to the standard analysis, is but six months old. Since the total nitrogen is low compared with the standard analysis, the absolute loss must be very large. The loss of nitrogen on air-drying the samples follows closely the results as given under the sheep manures, i. e., the loss is heaviest where there is the most free ammonia. There are some results in which an apparent gain is made on air-drying. The cow manures were much harder to sample than the sheep manures, and this probably accounts for some discrepancies in the results.

TABLE V.

Carbon and Hydrogen in Cow Manures.

The results are in percent of air-dried manure.

Sand and Silicic Acid Included				Sand and Silicic Acid Excluded	
No.	Age in years	Carbon	Hydrogen	Carbon	Hydrogen
1	1	20.450	2.690	35.188	4.630
2	2	23.920	3.193	37.961	5.067
3	3	18.480	2.418	35.735	4.676
4	10	23.564	3.388	31.833	4.577
5	10-12	6.884?	2.698	12.263?	4.806
6	3	25.414	3.256	32.982	4.226
7	½	24.871	4.029	36.876	5.974
8	½	27.092	4.313	37.887	6.032
9	1	28.412	4.001	39.321	5.537
10	2	20.784	3.208	34.354	5.302
11	2-5	19.983	2.859	36.071	5.161
12	10	18.946	2.739	34.546	4.995
13	18	12.266	1.366	34.771	3.863

Table V, like Table III, gives a series of carbon and hydrogen determinations which are remarkably close together. The average of the carbon determinations with sand and silicic acid calculated out is 33.8 percent and the hydrogen is almost an even 5 percent. Now the ratio of the carbon to the hydrogen in the sheep manures was 33.6 to 4.9 which are about the identical figures for the cow manures. There is then practically a constant amount of carbon and hydrogen in both sheep and cattle manures.

Some Miscellaneous Manures.

Table VI contains those manures which were not all of one kind, but are rather to be classed as mixed stable manures. Two of the manures, Nos. 44 and 45, are horse manure alone.

TABLE VI.

PERCENTAGE COMPOSITION OF MISCELLANEOUS MANURES, CALCULATED ON AIR-DRIED MANURE.

No.	Age Yrs.	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
37	2	64.224	35.776	7.344	38.500	45.844	27.260	6.106	1.175	26.825	0.808	2.024	1.373
38	6	50.749	49.251	3.507	68.763	72.270	57.190	6.140	0.684	11.555	0.181	1.204	0.832
39	4-5	55.623	44.376	6.184	42.005	48.189	25.820	3.622	0.976	23.155	0.095	1.387	1.499
40	10	58.897	41.103	6.007	42.661	48.668	26.271	3.302	0.972	26.575	0.136	1.661	1.485
41	20	57.402	42.598	2.746	58.935	61.681	45.800	6.203	1.353	7.720	0.035	1.908	1.313
42	3	52.115	47.885	2.327	55.049	57.376	45.730	5.106	1.055	7.250	0.027	1.520	1.417
43	6	40.344	59.656	0.910	68.102	69.012	59.741	2.214	0.560	2.360	0.020	1.149	1.104
44	Fresh	64.304	35.696	5.832	40.418	46.250	18.633	8.196	0.994	28.235	1.198	2.057	1.277
45	1¼	34.909	65.090	6.698	45.688	52.386	32.420	5.147	1.002	19.485	0.143	1.299	1.507

Notes on Table VI.

No. 37. Sheep and cattle. Pile 8 feet high. Very moist.
No. 38. Sheep and cattle. Pile 8 feet high.
No. 39. Sheep and cattle. In open corral undisturbed.
No. 40. Sheep and cattle. In open corral undisturbed.
No. 41. Horse, hog and cattle. In pile at least 15 years.
No. 42. Cattle and horse.
No. 43. Mixed stable manure. Considerable hay and dirt in the manure.
No. 44. Horse manure, made by work horses. Fed heavily on barley, bran, corn and alfalfa.
No. 45. Horse manure. Pile 6 feet high. Not much bedding used. Interior badly fire-fanged.

It will be noticed that the potash is high, and that the phosphoric acid runs about 1 percent. The moistures in the two horse manures are interesting in showing how this kind of manure practically burns up. At the end of 1 1-4 years there was only 35 percent moisture, and the whole interior of the pile was a mass of dry stems, so badly was it fire-fanged. It is rather surprising, however, to see how much nitrogen remained in the burned manure, although by far the greater portion of it had been lost.

Preservation of Manure.

Knowing at about what rate the manure deteriorates, and what elements of plant food are most easily lost, a few hints might not be out of place as to some waste which can be stopped by good management. Since the nitrogen, particularly as free ammonia, is the most easily lost in a dry climate, that is the substance we must preserve.

We have seen that piling up manure loosely causes intense bacterial action, and consequently loss of free ammonia. It will be best, therefore, to leave the manure in the corral until it can be hauled out and spread on the ground. If the corral must be cleaned, pile the manure in a shady place where its moisture will be retained. If at all possible and the weather is dry, moisten the manure with the hose after it has been placed in the pile; or, lacking any way of moistening the manure, try to clean the corral during wet weather.

Any method of compacting the manure pile to keep out the air will be found to help largely in conserving the nitrogen.

If both cattle and horse manure are produced on the farm, probably much of the horse manure could be rotted and yet not badly fire-fanged by mixing the two manures. Here, too, an occasional wetting would save much fertility.

Fresh sheep manure particularly should not be spread upon the land under our conditions, but rotting about six months, or at most a year, is all that is necessary to put the manure in fine condition for immediate assimilation by plants.

Recapitulation.

The main facts brought out by the deterioration experiment are as follows:

Manure under our conditions does not lose in weight as rapidly as in more humid regions. The sheep manure lost 32.5 percent in weight in about 15 months, and 56.7 percent in a little over two years.

About half (48.6 percent) of the total nitrogen was lost during the first 15 months, and 68 percent was lost in two years. The total nitrogen sustains the heaviest loss of any of the elements of plant fertility in semi-arid climates.

The phosphoric acid decreased 42 percent in 15 months, and 59 percent in two years. The loss in weight seems to fairly represent the loss of phosphoric acid.

The great difference between manures in semi-arid and humid climates is expressed in the potash. Practically all who have conducted experiments along this line mention potash as the most easily lost of the three elements of plant food, and that it is lost by leaching. Our manures retain the potash, probably due to the light rainfall. In the first 15 months no loss was found. The second year an absolute loss of 35 percent of the potash occurred. That the potash in fresh manure is soluble was demonstrated by experiment. Air-dried sheep manure lost 17.8 percent when washed with water, which represents a loss of 43.7 percent of the potash, 22.6 percent of the phosphoric acid, and 39.0 percent of the nitrogen.

From the 23 analyses of sheep manure, we learn that they contain on the average 13 percent less moisture than an average of sheep manures in moist climates.

The phosphoric acid remains at about one percent of the dry matter irrespective of the age of the manure.

The potash in this series of samples increases from an average of 4.4 percent in the fresh manures to 6.3 percent in the one-year-old samples, and remains at about this figure for several years, which corroborates the summarized statement in regard to the potash in the deterioration experiment.

There is a large loss of total nitrogen during the first two years. Almost the whole of this loss is due to a loss of free ammonia, which is produced in large amounts by the action of uro-bacteria.

The moisture in the manure plays a large part in retaining the free ammonia.

Nitrogen as nitrates varied widely. There was none in the fresh manures even after keeping the air-dried samples in the laboratory several years. As much as 27 percent of the total nitrogen was found present as nitrates in one sample. There was, however, no uniformity in the results, i. e., some of the older manures carried large amounts of nitrates while other samples of the same age carried almost none.

The carbon and hydrogen in manures are present in practically constant quantities, the age seemingly having nothing to do with the amount. This was true in both the cattle and sheep manures and in both the soluble ash is nearly a constant quantity.

Taking the results of all the tables as a whole, one is impressed by the sameness of the different determinations; especially is this true of the soluble ash, the potash, the phosphoric acid, the carbon and hydrogen. It is not true, of course, of the insoluble ash which increases decidedly with age, nor of the free ammonia and nitrogen which decrease with age. This sameness in the results means that, under our conditions at least, the manure is broken down by bacterial life at about the same rate that leaching carries away the soluble salts.