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CHEMICAL EXAMINATION

OF THE ASHES OF THE

HEMP AND BUCKWHEAT PLANTS,

WITH REMARKS ON ITS BEARING ON

HEMP CULTURE IN KENTUCKY.

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CHEMICAL EXAMINATION OF THE ASHES OF THE HEMP AND BUCKWHEAT PLANTS, &c.

The hemp crop is of considerable importance in Kentucky agriculture, more especially in the richer portion, called the Blue Grass region, where the soil has been formed by the disintegration of the fissile layers of the lower Silurian limestone—rich in the mineral elements of plant nourishment.

According to the State Auditor's report, the gross amount of hemp fibre produced in our State was 18,981,819 pounds in 1872, and 21,375,306 pounds in the more productive, moist season of 1873.

Of this latter quantity seventeen counties, situated wholly or in part in the Blue Grass region, produced 21,194,445 pounds, and the five counties of Bourbon, Fayette, Jessamine, Scott, and Woodford produced 17,951,350 pounds. Mason county, the next in this industry, having also raised 828,300 pounds. It is, therefore, evidently a crop which is believed to be profitable only on our richest lands. The soil which best suits it is the rich, pervious, and well-drained loam, well charged with *humus* or the dark mould resulting from vegetable decomposition, such as results from the completely decomposed sod of recently cleared woodland pastures, or blue grass or clover ground, well plowed and made thoroughly fine and uniform in texture. Such land, in a favorable season, has been known to produce as much as 1,200 pounds of hemp to the acre, and it will yield an average of about 800 pounds for ten to fifteen years in succession, if properly managed, in ordinary seasons. As the price of hemp rarely falls below one hundred dollars per ton of 2,240 pounds, and this crop usually brings in cash, the great value of this industry is evident.

The hemp plant, under favorable conditions, is of most rank and luxuriant growth, attaining on our rich lands a height of ten to fourteen feet in favorable seasons, even when sown so thick, as is the practice, that it is closely crowded, and so completely covers the ground that not a weed can grow amongst it. It therefore requires a soil which can readily and quickly furnish to it the mineral elements necessary to its rank and rapid development, and at the same time furnish the large supply of moisture it requires without losing that highly porous condition and absorbing power which invites the penetration of the gases and vapors of the atmosphere, on which this plant is so greatly dependent for nourishment and growth.

The well-drained loam of this Blue Grass region, which is charged with black vegetable mould or *humus*, offers these conditions; the *humus* not only having great power of absorption, but containing in a soluble and available state the mineral elements of plant nourishment, and, moreover, acting as a solvent for those which are contained in the earthy constituents of the soil itself. We can therefore readily understand why the hemp plant thrives upon such land; but why so luxuriant a growth can be maintained on the same surface for ten to fifteen years in succession, without any material exhaustion of the soil, is another question.

The observing hemp farmer has long since arrived at a correct conclusion in this respect. He saw that while this most luxuriant plant produced an immense green crop, and required the richest soil to supply its rapid demand for nourishment during its short season of growth (of four months only), yet all its leaves and other green tissues, together with all that is removed from it in the process of dew-rotting, in the ordinary mode of hemp culture, are restored to the soil which produced it, and nothing is sold and carried off from the land but the cleaned hemp fibre, which, if well cleaned, contains very little but atmospheric elements, the removal of which can therefore cause but very little deterioration of the soil.

Moreover, during a great part of the year the ground is more or less shaded and protected, first by the growing plant,

then by the roots left in the ground after cutting, which somewhat diminish the washing action of rains and improve it in their gradual decay, as do also the leaves which fall and the hemp when spread on the ground to dry, after being cut, and lastly, when it is spread out upon it in the winter process of dew-rotting, as it is called, during which all the readily decomposable parts of the plant are washed out and decomposed by the rains and dews and the action of the air; enriching the surface soil beneath.

Managed in this way, and commencing with suitable rich land, the scientific observer understands, that although the growing plants may temporarily draw heavily on the soil for the mineral (earthy) ingredients necessary to their growth, amongst the most important of which are potash and the earthy phosphates, yet in the subsequent processes, the most of these are returned to the ground again in the decay of the leaves and other green parts, and in the soluble and decomposable matters which are leached out of the stems in the process of rotting; and that any small loss of these from the arable surface which may occur from the sale of the hemp fibre may be more than compensated by the action of the tap-roots in bringing them up from the lower strata of the ground. He understands further, that all the mineral elements thus restored, being left in organic combination in what is termed the humus or vegetable mould which results from this decay, are in a very soluble condition, and most available for the quick nourishment of the subsequent crop.

If the hemp plant, instead of being dew-rotted on the ground on which it had been grown, is entirely removed from it and submitted to the process of water-rotting, the culture becomes eminently exhausting to the land; mainly because so much of the elements of fertility is necessarily carried off in the water used. This was proved many years ago in relation to the flax crop of Ireland, in the chemical analyses of the water in which the flax had been steeped, and of the plant and the lint, by Dr. Kane; and experience to a certain extent in this region, in the water-rotting of hemp, has given the

same result. It is, perhaps, fortunate for our farmers, therefore, that this process, although several times proposed to them, has never been received with much favor.

The foregoing facts being of common experience, the writer desired, by the chemical examination of the mineral or earthy constituents of the hemp plant, as given in the *ash* in different periods and conditions of its growth, in different parts of the plant, and the various stages of its preparation, to study more fully the relations of this crop to the soil, and to understand, if possible, the true reasons why it is not an exhausting product when properly managed, as well as to learn the best conditions for its successful culture.

The first step in this investigation is to ascertain the average composition of the mineral ingredients of the entire hemp plant as given by the chemical analysis of its ashes; and as the works accessible to the writer give but very limited information on the subject, he procured from his own farm, and submitted to this analysis, five different samples, produced in two different seasons, grown under different conditions, and collected in different stages of their growth. The ashes of these, obtained by careful incineration at a moderate heat, were analyzed by the approved processes—several comparative analyses of the same ash having been made to secure greater accuracy—and the results are tabulated below in comparison with the average of two hemp-ash analyses published in 1865 by Professor Emil Wolff, of the Royal Academy of Agriculture, at Hohenheim, Wirtemberg, which are republished in the Appendix, page 378, of "How Crops Grow," by S. W. Johnson.

The samples examined may be described as follows:

Sample A. Entire hemp plants, including roots, leaves, &c.; collected on September 4th, 1874, when fully mature and ready for cutting; grown on somewhat elevated, very rich ground, the second year only from the broken up blue grass sod of woodland pasture, which had not been previously cleared or cultivated within the memory of the present race,

but which had been the site of a large circular earth-work* by the ancient mound-builders, and which seemed to have been enriched by a long residence upon it of these prehistoric people. The sample, notwithstanding the great fertility of the land, was very small, in consequence of *a continued drought which prevailed during the season of its growth*, it not being more than six to seven feet in height.

Sample B. Mature hemp plants, taken as it is usually cut, the roots and a small portion of the stems being left in the ground, and having only the top leaves, the others having fallen; collected September, 1873; grown on the field described above *in a very moist and favorable season*, so that it was very tall and large stemmed. The samples were about twelve feet high. Some hemp plants this year attained a height of fourteen feet.

Sample C. Six hemp plants entire, leaves, roots, and all; collected, before full maturity, on July 27th, 1874, from the same rich field, in the *very dry season*. The plants were about six feet high, and were in full leaf and in flower.

Sample D. Entire hemp plants, including roots, leaves, and immature seeds; grown on the experimental field selected by my son, Benj. D. Peter,† for practical experiments in hemp culture. This ground had been long in cultivation—at least fifty years. This sample was grown on lot 3, to *which about 200 pounds of plaster had been applied* early in the growing season. The sample was collected on September 8th, 1874. The plants were quite small, not more than from five to six feet high, in consequence of the continued drought of this season and the condition of the land.

Sample E. Similar to sample D; grown on the neighboring lot 4, of this experimental field, under similar conditions, except that *no plaster or any other fertilizer was applied to this lot*. A part of this lot 4, however, where a fence row formerly stood, happened to be somewhat richer than any part of this

* Fully described in Collins' History of Kentucky.

† See Prof. N. S. Shaler's Report.

or the plastered lot, as shown by the greater luxuriance of the growth of the hemp in that part.

F. The average of the analyses of the ashes of two entire hemp plants as given by Prof. Emil Wolff, as above stated.

In this table, as well as in the following ones, the carbonic acid of the ash is excluded in the calculations, for more complete comparison of the proportions of the *essential* mineral ingredients of the ash.

TABLE I. A. OF THE CHEMICAL COMPOSITION OF THE ASH OF THE ENTIRE HEMP PLANT, CALCULATED IN 100 PARTS OF THE ASH, WITH EXCLUSION OF CARBONIC ACID.

	A.	B.	C.	D.	E.	F.
Lime	38.482	31.299	48.689	50.623	45.263	43.4
Magnesia	8.558	6.017	6.445	8.576	11.225	9.6
Potash	37.475	43.739	29.118	23.519	23.933	18.3
Soda . . . . .	.378	1.438	1.280	.472	.009	3.2
Phosphoric acid	8.667	14.164	10.384	11.721	13.233	11.6
Sulphuric acid	2.272	1.622	.940	1.472	1.445	2.8
Chlorine . . . . .	.984	.522	.640	.301	.273	2.5
Silica	3.181	1.199	2.749	3.316	3.342	7.6
Per cent. of earthy phosphates . .	18.186	29.773	21.692	28.460	27.427	. . . .
Per cent. of ash to the air-dried plants, carbonic acid excluded .	4.223	2.563	5.055	4.126	4.203	4.6
Per centage of ash, carbonic acid included	5.569	3.357	6.754	5.288	5.346	. . . .

This table shows some notable differences in the ash proportions and composition. For example, sample B, grown in the moist season, as compared with the others grown during the drought, gave a smaller ash per centage to the dried plants; its ash contains smaller proportions of lime, magnesia, and silica, and larger proportions of potash, soda, and phosphoric acid.

The immature sample C, gathered in July, as compared with the other samples (A, D, and E) of the same dry season, which were gathered in September, shows a larger per centage of ash to the dried plants.

The samples D and E, grown on the old land, while they give about the same average of ash to the dried plants, show a smaller proportion of potash.

Not much importance is attached to the proportion of silica, which is evidently stated much too high in the analyses quoted by Wolff. The hemp plant, being somewhat viscid on its exterior, always has more or less fine silicious dust adhering to it, derived from the soil, which cannot be removed by washing the plants. This the writer attempted to exclude, in his analyses, by dissolving the ash in diluted acid (nitric or chlorohydric), and excluding all that remained undissolved as most probably fine earth accidentally adhering to the plant. This may, in some cases, be a slight cause of error, but probably not so great as the retention and analysis of the adhering fine dirt with the plant ash, which seems to have been done in the analyses quoted by Wolff. For the same reason the alumina and iron oxide were also excluded.

The real significance of these differences of proportion and composition of these ashes can better be seen where the comparison is made with the proportions of the dried plants themselves to the several ingredients of the ash, as given in the following table:

TABLE I. B. OF THE QUANTITIES OF THE ASH INGREDIENTS IN 100 PARTS OF THE AIR-DRIED HEMP PLANTS, CARBONIC ACID EXCLUDED.

	A.	B.	C.	D.	E.	F.*
Lime	1.624	0.802	2.461	2.103	1.968	1.74
Magnesia . . . . .	.361	.154	.312	.356	.475	.30
Potash	1.582	1.121	1.472	.977	1.012	.74
Soda . . . . .	.016	.037	.065	.019	a trace.	.15
Phosphoric acid . . . . .	.366	.363	.525	.488	.560	.47
Sulphuric acid . . . . .	.096	.042	.047	.061	.061	.10
Chlorine . . . . .	.041	.013	.022	.012	.011	.10
Silica . . . . .	.134	.031	.139	.135	.141	.30
Per cent. of earthy phosphates . .	.768	.763	1.103	1.182	1.150	. . . .
Per cent. of ash to dried plants . .	4.223	2.563	5.055	4.126	4.203	4.00

* See Wolff's tables, "How Crops Grow," page 383. Calculated to the dried plants.

This table shows, that while the smallest proportion of mineral or ash ingredients, to the dried plants, was given in the season when the hemp had a luxuriant growth because of the regular supply of moisture, the difference was occasioned mainly by the greater quantities of lime, magnesia, and silica in the plants of the dry season, and not by any material variations in the proportions of the alkalies or phosphoric acid.

It is well known that the external tissues of all growing plants become more or less charged with earthy salts, especially carbonates of lime and magnesia with some phosphates, which have been carried from the soil to their surfaces in solution in water containing carbonic acid (which is in all the water of the soil) and left there in a form insoluble in water upon the escape of that acid and the evaporation of the water which brought them up. As all the moisture of the fertile earth contains this solution, which is drawn up and evaporated from the general surfaces of the plants exposed to the air, it can readily be seen, that because of the greater evaporation and the more concentrated nature of the soil solution, in the dry season, there must necessarily be a larger accumulation of this surface deposit in the dry than in the moist or wet season, when evaporation is measurably checked. For the same reason the ash per centage of the leaves and bark of plants is greater than that of the interior parts, and that of the leaves of deciduous plants greater than that of the leaves of evergreens, which give off less water by evaporation.

The effect of this evaporation has very justly been compared to the deposit of the limestone crust in the steam-boiler and the formation of stalactites in caves; and this irregular increase of the ash per centage causes many apparent discrepancies in the mineral ingredients of plants, and increases the difficulties in the chemical study of plant nourishment; for while it is generally admitted as fully demonstrated, that certain mineral ingredients, to be found in the ashes of all vegetables, are essentially necessary to their growth, it must be acknowledged that some or some portion of these ingredi-

ents are of no more significance than the incrustation in the steam-boiler; being mere accidental deposits on the surface, the result of the escape and evaporation of the agents, water and carbonic acid, which held them in solution in the sap of the plants and in the water of the soil.

In the same manner may we explain the influence of a dry season in increasing the fertility of the surface of the soil; the soil solution, on the evaporation of the water, leaving its dissolved salts and other ingredients upon the surface; so that seasons of long drought are usually followed by others of great productiveness when there is sufficient moisture.

The larger ash per centage of sample C is mainly due to this cause; the leaves not having fallen, which yield a very large proportion of ash.

The ashes of samples D and E, grown on the old land in the very dry season, while not differing much in their general weight-proportion to the dried plants, show more lime and less alkalies than that of the hemp grown on the richer land. For some reason not immediately apparent, perhaps because of a previous buckwheat crop, they gave rather more than the average quantity of earthy phosphates.

In the usual mode of management of the hemp crop the leaves mostly fall on the ground on which it is grown. A large proportion of them drop before the hemp is cut, more fall when it is spread on the ground to dry after cutting, and when it is taken up to be stacked. It would be well, doubtless, to beat off, in this process, all the leaves that can thus be separated, so that they may be more regularly distributed over the soil than if thrashed off when stacking it. It is also the general practice now to cut the hemp as nearly as possible to the surface of the ground, and leave the roots, with a few inches of the stem attached, to rot in the soil.

In order to ascertain the relative fertilizing influence of the leaves and roots, three hemp plants were collected, July 25th, 1864, in *the dry season*, from the rich field above described. These, one male and two female plants, were about six to

seven feet high. The leaves, stems, and roots, carefully separated and thoroughly air-dried, weighed as follows:

The leaves weighed 23.916 grammes, equal to about 30. per cent. of the whole plant.
 The roots " 7.433 " " 9.3 " "
 The stems " 48.430 " " 60.7 " "

These were separately incinerated and their ashes analyzed, with the following results:

TABLE II. OF THE RELATIVE ASH INGREDIENTS OF THE LEAVES, ROOTS, AND STEMS OF THE HEMP, CARBONIC ACID EXCLUDED.

	THE LEAVES.		THE STEMS.		THE ROOTS.	
	In 100 p'ts of ash.	In 100 p'ts of dried leaves.	In 100 p'ts of ash.	In 100 p'ts of dried stems.	In 100 p'ts of ash.	In 100 p'ts of dried roots.
Lime	48.819	4.992	23.371	0.949	20.368	0.713
Magnesia	5.726	.585	5.803	.194	8.297	.291
Potash	27.955	2.858	49.599	1.659	52.233	1.829
Soda . . . . .	.236	.024				
Phosphoric acid	9.264	.947	13.374	.447	15.164	.531
Sulphuric acid	2.209	.226	1.215	.040	1.344	.047
Chlorine171	.017	.576	.019	.405	.014
Silica	5.620	.575	1.062	.035	2.189	.077
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Per cent. of phosphates	19.160	1.959	28.158	0.942	26.885	0.949
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Per cent. of ash		10.225		3.346		3.502

By examination of the above table it is to be seen, that the leaves of the flowering hemp contain more of the essential mineral ingredients of the soil than all the other parts of the plant; constituting, as they do, about 30 per cent. of the whole plant in the air-dried state, and yielding 10.225 per cent. of their weight of ash, the carbonic acid being excluded; while the stems and roots, which together form the remaining 70 per cent. of the weight of the plant, give an average of less than 3.5 per cent. of ash.

Nor is this great excess of the ash proportion in the leaves due entirely to the influence of the greater evaporation which takes place on their surfaces, causing a deposit or incrustation of lime and magnesia salts and silica of the nature of stalagmites; for we see that whilst the amount of *silica* in the leaves is nearly fourteen times greater than that in the stems, and

more than seven times greater than in the roots; the *lime* more than five times as great as that in the stems, and seven times more than in the roots; the *magnesia* three times more than that in the stems, and twice as much as that in the roots; the *phosphoric acid* and *phosphates* and the *alkalies* are in nearly double proportion in the leaves also, and the sulphuric acid five times greater in them than in the stems, and about four times greater than in the roots. So that whilst the leaves, when in their fully matured state or when they naturally fall, may possibly contain scarcely any but the less soluble salts which may be left in their tissues on the evaporation of the carbonated water which held them in solution in the sap, they contain, when in the growing, active condition, like all other green herbage, a very large proportion of salts of potash, and of all the mineral elements of plant nourishment, and hence may greatly enrich the soil on which they decay. It is obviously to the interest of the hemp farmer, therefore, so to manage as to spread them as regularly as possible over his hemp ground.

The dried hemp plants are allowed to remain in the stack until the cool season of early winter, when they are generally spread out evenly upon the same ground on which they had been grown, to undergo the process of dew-rotting. The hemp is permitted to remain on the ground until, by the action of the atmospheric waters and other agencies, it has become so far decomposed that all its soluble parts and soft tissues are removed and washed into the soil beneath or dissipated in the air, and the tough hemp fibre can be easily separated from the more woody portion of the stems. It is then taken up, "braked" out, and the clean merchantable hemp fibre separated from the "hemp-herds," or "*hemp shives*"—the broken fragments of the woody parts of the stems—which are usually burnt up by the hemp-brakers on the spots where they fall near their hemp-brakes.

In order to study the changes which occur in the mineral constituents of the hemp during this process of dew-rotting, samples of dew-rotted hemp plants, ready for the brake, were

gathered, in December, from the two lots of the experimental field above mentioned, of the crop of the dry season of 1874. These were thoroughly air-dried, incinerated, and their ash submitted to analysis, with the following results:

TABLE III. OF THE ASH ANALYSES OF DEW-ROTTED HEMP PLANTS, CARBONIC ACID, &c., EXCLUDED.

	(D) SAMPLE FROM LOT 3. PLASTERED. (SEE D.)		(E) SAMPLE FROM LOT 4. NOT PLASTERED. (SEE E.)	
	In 100 parts of ash.	In 100 parts of dried hemp plants.	In 100 parts of ash.	In 100 parts of dried hemp plants.
Lime	68.846	1.235	63.651	0.942
Magnesia	8.335	.149	8.343	.124
Potash	5.716	.102	5.682	.084
Soda . . . . .	.429	.008	.760	.012
Phosphoric acid	13.979	.251	15.713	.233
Sulphuric acid . . . . .	.965	.017	1.552	.023
Chlorine . . . . .	.050	.001	.042	.001
Silica	1.680	.030	4.257	.063
Per centage of earthy phosphates	27.144	.487	29.920	.443
Per cent. of ash to the dried rotted hemp		1.793		1.480

On comparing these results with those given in tables I. A. and I. B., in the columns D and E, where the results of the analyses of the ashes of this same growth of hemp are given in the *unrotted* state, it will be seen that a great diminution has taken place in the amount and proportions of the ash and its several ingredients.

To exhibit this diminution of the ash ingredients, which takes place in the ordinary process of dew-rotting, we place the averages from table I. B. and the above table side by side in

TABLE IV. COMPARATIVE VIEW OF THE ASH OF THE UNROTTED AND THE DEW-ROTTED HEMP PLANTS, CARBONIC ACID BEING EXCLUDED.

	Average of D and E. Un- rotted hemp plants.	Average of D and E. Dew- rotted hemp plants.	Proportions removed by dew- rotting.
Lime	2.036	1.089	About one half.
Magnesia . . . . .	.415	.136	Nearly two thirds.
Potash . . . . .	.995	.093	More than nine tenths.
Soda . . . . .	.019	.010	About one half.
Phosphoric acid . . . . .	.524	.242	More than one half.
Sulphuric acid061	.020	About two thirds.
Chlorine011	.001	Ten elevenths.
Silica138	.047	Nearly two thirds.
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Per cent. of earthy phosphates	1.166	.465	More than one half.
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Per cent. of ash to the dried plants	4.165	1.636	More than one half.

When we also take into consideration the fact that the dried hemp plants lose at least one third of their weight in the dew-rotting, we can judge how large a proportion of the essential mineral ingredients are restored to the soil in this process.

The above table also shows us that the more soluble ingredients, such as the alkalies, &c., are removed from the plants in the larger proportions.

These analyses and comparisons enable us clearly to understand why the culture of hemp, when judiciously managed, especially when it is spread out and dew-rotted on the same surface on which it was grown, is so little exhausting to the soil, as compared with the method in which the water-rotting process is used.

In order to ascertain how much of the essential elements of the soil are carried off in the merchantable product—the hemp fibre as ordinarily sold—analyses were made of some of this, both in the usual condition as it is to be found in our hemp factories, and after it had been well washed with water to remove from it as much of its adhering dirt and soluble matter as possible.

Two samples of the “hemp-herds,” or refuse woody portions of the stems, separated in the operation of braking, were also incinerated, in the air-dried state, and the ashes

submitted to chemical analysis. The results are given in the following table:

TABLE V. COMPARISON OF THE ASH INGREDIENTS OF DEW-ROTTED HEMP FIBRE AND HEMP HERDS, CARBONIC ACID EXCLUDED.

	HEMP FIBRE, UNWASHED.		HEMP FIBRE, WASHED.		HEMP-HERDS, 1873. MOIST SEASON.		HEMP-HERDS, 1874. DRY SEASON.	
	In 100 p'ts of ash.	In 100 p'ts of dried hemp.	In 100 p'ts of ash.	In 100 p'ts of hemp.	In 100 p'ts of ash.	In 100 p'ts of dried herds.	In 100 p'ts of ash.	In 100 p'ts of dried herds.
Lime	59.960	0.984	68.694	0.722	51.998	0.446	62.992	0.676
Magnesia	8.512	.141	6.222	.065	8.426	.072	8.966	.097
Potash	7.351	.121	3.789	.040	19.615	.168	8.670	.093
Soda . . . . .	.712	.012	.801	.008	.915	.008	.754	.008
Phosphoric acid	15.852	.200	15.335	.161	14.401	.124	12.215	.131
Sulphuric acid	1.710	.029	.487	.005	2.016	.017	2.138	.023
Chlorine . . . . .	.092	.002	.048	.001	a trace.	a trace.	a trace.	a trace.
Silica	5.621	.042	4.624	.049	2.629	.022	4.465	.048
Per cent. of earthy phosphates	31.567	.515	29.486	.310	29.275	.251	24.807	.267
Per cent. of ash to the air-dried material		1.642		1.051		.859		1.076

The hemp fibre, which was analyzed in the ordinary unwashed condition, was obtained from a factory in Lexington. It was of the crop of 1874, dark colored, and containing, perhaps, more than the average quantity of dirt or fine soil adhering to it. Washing with cold water removed some but not all of this adhering dirt, as well as much of the soluble matters contained in it, reducing the per centage of the ashy residue more than one third. Had it been thoroughly cleaned and bleached the ash per centage would have been still more considerably reduced. All the nitrogenous matters, holding phosphates in a comparatively soluble condition, all the alkaline salts, would thus be dissolved out, and very little else than silica, with a small proportion of the earthy carbonates, would be left in the clean hemp fibre; so that exhaustion of the soil from its production would be quite insignificant.

Calculating on the data of the above tables, we find that an average crop of hemp of 800 pounds to the acre removes from the soil only a little more than thirteen pounds of ash ingredients, or, when in the washed condition, less than eight pounds and a half, while it is well known that a crop of wheat of twenty bushels takes nearly twenty pounds in the grain

alone; a crop of fifty bushels of corn removes more than thirty pounds in the grain alone, and a crop of tobacco of one thousand pounds, more than one hundred and seventy-six pounds.

When we compare the relative proportions of the ingredients of these several ashes, the result is still more to the advantage of the hemp crop, as is to be seen in the following table:

TABLE VI. OF THE PROPORTIONS OF MINERAL INGREDIENTS REMOVED FROM THE SOIL IN CERTAIN AVERAGE CROPS.

	In 800 lbs unwashed hemp.	In 800 lbs of washed hemp.	In 20 bus'ls of wheat *	In 50 bus'ls of corn.*	In 1,000 lbs tobacco, in- cluding the stalks.*	In 2,400 lbs of ordinary hemp-h'ds.
Lime, in pounds	7.872	5.776	1.63	0.22	68.00	10.704
Magnesia, "	1.128	.520	2.43	3.61	8.67	1.728
Potash, " . . . . .	.968	.320	5.45	8.06	69.73	4.032
Soda, " . . . . .	.096	.064	.13	6.22	6.80	.192
Phosphoric acid, "	2.080	1.288	9.12	11.85	8.13	2.976
Sulphuric acid, " . . . . .	.232	.040	.08	not est.	8.40	.408
Chlorine, " . . . . .	.016	.008	.35	not est.	1.06	a trace.
Silica, " . . . . .	.736	.392	.41	.71	5.86	.528
Total ash	13.128	8.408	19.60	30.67	176.65	20.568
Total earthy phosphates	4.144	2.480	. . . . .	. . . . .	. . . . .	6.024

* From volume IV, Reports of Kentucky Geological Survey (old series), page 321.

We see that while an average crop of hemp takes only an amount of potash from the acre varying from less than one pound to less than one third of a pound, the wheat crop takes nearly five and a half pounds, the corn crop more than eight, in the grain alone, and the tobacco crop nearly seventy pounds; and while the hemp crop carries off only from one and a quarter to two pounds of phosphoric acid, the wheat will take more than nine, the corn more than eleven, in the grain alone, and the tobacco more than eight pounds. We notice also that the removal of the hemp-herds (which are believed by some of our practical farmers to bear a proportion in weight to the hemp fibre of three to one) will take from the land greatly more of its essential ingredients than the hemp fibre itself; for while the merchantable hemp holds less than a pound of potash and two pounds of phosphoric acid in its composition,

the equivalent quantity of hemp-herds holds more than four pounds of potash and nearly three pounds of phosphoric acid.

As we have stated, it is the common practice of our farmers to permit the hemp-herds to be burned up in the heaps where they fall near the hemp-brakes. Some erroneously believe, indeed, that they would exert an injurious or poisonous influence on the land if spread over it; but it is evident that this practice tends more rapidly to reduce the fertility of the hemp field than the sale of the hemp fibre; and that it would be beneficial to adopt some plan of reducing the hemp-herds to the condition of vegetable mould, and to spread it over the surface, where it would not only tend to keep up the proportion of humus, but would re-supply much of the essential mineral elements in a soluble or available form. If it is found that the recently scattered hemp-herds seriously interfere with the cultivation or growth of the next succeeding hemp crop, it would doubtless pay to haul them into heaps to rot, or to spread them over some other field, which might be in preparation for hemp in a system of rotation adapted to this culture.

The common practice in our region has been to cultivate the rich new land in hemp continuously until it no longer yields a profitable product, and then to resort to other newly-cleared woodland pasture, or open blue grass fields, to renew the process. Sometimes land comparatively old in cultivation has been used for hemp, after it has been rested and has increased its humus during two or three years in clover, or for a longer time in open blue grass pasture; but as yet no regular system has been adopted by which the abundant humus and ready supply of soluble mineral ingredients of the soil, necessary to this luxuriant vegetation, can be secured or maintained. As the hemp product carries but little of these away from the land, leaving most of them behind, after a temporary use of them during its season of growth, the maintenance of the productiveness of the hemp soil seems an easy problem to solve, where the land is well drained and naturally of a suitable composition and consistence, as is our blue grass

land. But the capability of the production of hemp, even in this fertile soil, appears to be limited, and its humus and other soluble essential ingredients, on the abundance of which this crop is so greatly dependent, seem gradually to undergo diminution in the ordinary system of culture.

That this gradual deterioration is not due wholly to the removal of the crop is evident from the foregoing facts and considerations. But it appears that the humus and its soluble and available constituents are decomposed and removed, under the influence of the atmospheric agencies, faster than they are renewed by the decay of the leaves and other decomposable parts of the hemp plant. The small proportions of these carried off in the merchantable hemp need, indeed, scarcely be taken into consideration in this connection.

The humus is a very decomposable and oxidable substance; the atmospheric oxygen combines continuously with its carbon and hydrogen to produce carbonic acid and water, so necessary as plant food, while the essential mineral elements of the mould thus set free, being in a soluble condition, are subject to the washing agency of water, which may diffuse them more or less through the neighboring fields, or gradually carry some of them off in the drainage. This action would be the greatest when the ground is no longer covered with a growing vegetation, which would absorb the rich soil solution and bring its valuable fixed ingredients to the surface, but is doubtless constant whenever water in sufficient quantity falls to saturate the soil or to pass through it. For although many experimenters have established the fact that the soil has a power of absorption sufficient not only to enable it to withdraw and hold certain substances dissolved in the water which passes through it, and even to decompose some chemical compounds, and to separate and hold some of the elements and replace them by others less essential, yet it is equally well established by numerous experiments that pure water, such as rain water, which passes through a fertile soil, carries off from it, in solution, a notable quantity of its essential elements, which, as already intimated, may either be lost to the locality by the

drainage or diffused through the adjoining grounds, according to the well-known laws of osmose.

To maintain the high degree of active fertility necessary to successful hemp culture, even in our rich blue grass lands, seems, therefore, to require something more than the most judicious management of that crop itself; for we find that, although the removal of the hemp causes a scarcely sensible diminution of the mineral elements of the soil, the field on which it is continuously produced for a series of years becomes at length unproductive of this crop, because, doubtless, of a gradual decrease of its proportions of humus and of those soluble salts which are required by the hemp plant in such a large and ready supply as is necessary to its rank and rapid development, during its short season of growth.

As the prevalent mode of culture, if carried on indefinitely, would inevitably reduce all our hemp lands below the level of profitable production, the adoption of a new system, which would promise greater durability to hemp culture, is greatly desirable.

According to the prevalent system, the hemp ground is exposed, more or less, to the decomposing and leaching influence of the atmospheric agencies for more than six months in the year, with scarcely any growing plant upon its surface to absorb and retain the dissolved fertilizing materials or the nutritive gases which are produced in it by decomposition. These, therefore, may pass off in the drainage or become lost to the field by the continuous process of diffusion.

The growth of the hemp begins early in May; it is ended, by the cutting of the crop, late in August. During these four months it is probable the active vegetation absorbs and retains the dissolved essential elements of the soil, so that waste of them by oxidation, diffusion, or drainage, is little or nothing. The drying of the cut hemp spread on the ground is a short process, and the subsequent influence of the roots of the hemp left in the ground is merely mechanical, and does not prevent oxidation of the humus or the leaching out or diffusion of its soluble materials; neither does the hemp, when

spread out to dew-rot, prevent this action of the atmosphere or the water, although it may give much soluble fertilizing matters to the soil; and very few weeds of any kind spring up in the hemp field to take up and retain for future use these valuable gaseous and soluble substances which pervade the soil, and are escaping, mostly in solution, in all the water which passes through it.

The obvious remedy for this loss is to keep the surface of the ground, as much as possible, covered with an active vegetation which would absorb and retain upon the surface these fleeting elements of fertility, and keep up, in its subsequent decay, the large proportion of humus which is necessary to a heavy hemp production.

Some of our farmers, for this purpose, have very judiciously resorted to the sowing of rye after the cutting of the hemp, to be plowed in, the following spring, as early as may be necessary to kill it and allow it to rot. The rye grows with great vigor and covers the ground fully; is not injured by the hardest frost, and offers no impediment to the dew-rotting of the hemp, while its roots continually absorb the soluble and gaseous elements of plant food, to retain them and leave them in an available state, together with a new supply of humus, when it is plowed in to decay in the soil. If at the time of sowing the rye the ground is also plowed and the hemp roots covered to rot, no doubt the surface could be more benefited than if the grain is simply sown on the surface and harrowed in.

Some definite idea of the beneficial influence of the rye may be obtained by examining the results of the analyses of this plant in its immature condition, as given in the tables of Emil Wolff and Dr. Emmons, of New York. (See table in Johnson's "How Crops Grow" and "Natural History of New York.")

It would be quite a moderate estimate to say that rye, sown on the rich hemp ground in early September and plowed in early in April or late in March, would give to the land an amount of vegetable matter, in its roots and leaves, equal to three thousand five hundred pounds, in the dried condition, to

the acre, which by its decay would greatly increase its vegetable mould or humus, and probably replace fully that portion which had been removed in the hemp culture. But we find, by reference to the table of Wolff, that this amount of organic matter would also give to the soil more than sixty-six pounds of potash; more than twenty-five pounds of phosphoric acid; nearly thirteen pounds of lime; more than five pounds of magnesia; more than two pounds of sulphuric acid, and equally considerable quantities of soda, chlorine, and soluble silica; in all more than one hundred and seventy pounds of essential mineral ingredients to the acre, in a state most favorable for plant food, or nearly twenty times as much as need be carried off in an average crop of merchantable clean hemp fibre. This use of the rye plant evidently commends itself to the careful and judicious hemp farmer for a full and thorough trial.

Another important question with our hemp farmers is, how best to improve our old fields to a new capability of profitable hemp culture? Such is the natural fertility of our blue grass soil, and so very favorable are the conditions to which it is subject, that this is a more easy problem than is generally supposed. Indeed, our routine farmers find by experience that a good clover rotation, or a series of years in blue grass sod, will ordinarily recuperate a field to hemp land. The soft Silurian limestone beneath it is constantly, although slowly, yielding up its stores of fertilizing elements to the atmospheric waters, which gradually dissolve it and bring them by diffusion into the soil for the use of growing plants. But the demands of the farmer upon the soil most generally exceeds this beneficent supply of fertilizers, and hence his fields decrease in productiveness in the ordinary thriftless husbandry which has been kept up by this liberality of nature, and he is already confronted with the necessity, either for the use of artificial fertilizers or the adoption of such a system of rotation of crops as will give time for the natural recuperation of his soil, without a serious diminution of his annual income. The latter alternative commends itself most in our region, and especially a rotation which includes a clover fallow of two years. The

red clover growing with great vigor on our ordinary soil; producing a great amount of herbage; drawing largely from the atmospheric gases and vapors, and reaching to considerable depths in the soil for mineral fertilizers with its long tap roots; so that experience proves it to be the best known plant for the renewal of our land, in our common rotations, more especially because it can be pastured with hogs or cattle without a very serious diminution of its ameliorating influence upon the soil. When cut for hay, which is removed from the field, the case is very different, as can be understood when we see that a clover hay crop of two tons carries off with it not only the equivalent of humus which its decay on the soil would give, but also more than eighty pounds each of potash and lime, nearly twenty-three pounds of phosphoric acid, and other fertilizing mineral substances in proportion.

The ash of the dried clover and dried green hemp plant are strikingly alike in composition, as may be seen in the following table:

TABLE VII. OF THE RELATIVE PROPORTIONS OF THE ASH CONSTITUENTS OF CLOVER AND HEMP PLANTS, &c.

	In 100 parts of the dried hemp. From table I. B. (Sample C.)	In 100 parts of dried clover. (E) From Wolff's tables.*	Mineral ingredients in an acre of clover, including the roots. (Say 5,000 lbs., dry.)
Lime	2.461	2.30	115.00 pounds.
Magnesia . . . . .	.312	.80	40. "
Potash	1.472	2.30	115. "
Soda . . . . .	.065	.10	5. "
Phosphoric acid . . . . .	.525	.65	32.5 "
Sulphuric acid . . . . .	.047	.20	10. "
Chlorine . . . . .	.022	.25	12.5 "
Silica . . . . .	.139	.20	10. "
Per cent. of ash	5.055	6.80	340. pounds.

* The average of fifty-six analyses.

That the clover fallow may be made very useful in the renovation of our hemp lands, by a judicious management, is manifest.

But other plants of a quicker growth may sometimes enter into an improving rotation for this crop, and no other promises

better than the *buckwheat plant*, in ordinary seasons, which may afford moisture enough for its luxuriant growth.

During the present year my son, Benj. D. Peter, devoted one lot in his experimental field (see Prof. N. S. Shaler's report) to buckwheat, sown broadcast in the spring, in order to study its ameliorating influence on the soil when plowed in. The season being a very wet one, the plants grew with great luxuriance and fully covered the ground. Samples of it were gathered by me, roots and all, on June 20th, when it was in full leaf and in flower at the top; and also on August 4th, when it was about three feet high, yet in flower at the top, and had matured a good deal of seed. It had, of course, then lost most of its lower leaves. These samples were fully air-dried in the laboratory, incinerated, and the ashes fully analyzed, with the following results:

TABLE VIII. OF THE COMPOSITION OF THE ASH OF THE BUCKWHEAT PLANT, &c., CARBONIC ACID EXCLUDED.

	BUCKWHEAT IN FLOWER.		BUCKWHEAT IN SEED.	
	In 100 parts of the ash.	In 100 parts of dried plants.	In 100 parts of the ash.	In 100 parts of dried plants.
Lime	33.434	2.979	35.103	2.131
Magnesia	10.518	.922	12.586	.764
Potash	32.900	2.883	26.180	1.589
Soda	1.266	.111	.657	.040
Phosphoric acid	16.824	1.470	23.770	1.443
Sulphuric acid	1.378	.120	not est.	not est.
Chlorine . . . . .	.431	.078	.350	.021
Silica	3.249	.285	1.354	.083
Per cent. of earthy phosphates	32.873	2.880	47.198	2.865
Per cent. of ash in dried plants		8.762		7.479
Per cent. of dried to green plants		18.000		29.000

This crop of green herbage was plowed under shortly after the last sample was gathered, in the hope that the matured seed would germinate and produce a second growth to be plowed under in the fall. Many did sprout, but the grasshoppers consumed most of the young plants.

Before plowing this buckwheat under, the green growth on a yard square was weighed, and amounted to four and three quarter pounds, which is equivalent to about 22,990 pounds to the acre, equal to more than six thousand pounds, or three tons, of the dried plants, including the roots, to the acre of ground. So that, calculating on the data given in the above table, this large quantity of green herbage, with the seeds and roots included, would not only give to the surface the large amount of humus, or vegetable mould, which would result from its decomposition, but also more than ninety-five pounds of potash; more than eighty-six pounds of phosphoric acid; nearly one hundred and forty pounds of lime; nearly forty-six pounds of magnesia, and other essential ingredients in proportion; all in a state immediately available for plant nourishment.

The experience of another season may demonstrate its practical effect in an increased hemp production.

The buckwheat plant is used in other regions as a fertilizer, and may very properly be introduced here in a rotation. It is evident that future profitable hemp culture will depend greatly on the adoption of a judicious rotation of crops suited to our soil and markets. What the details of that rotation may be must be worked out by our intelligent farmers.

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INDEX.

[The figures refer to the bottom paging.]

Action of plants on rock materials	431 to 433
Airdrie Furnace iron ores, &c.	145, 148, 149, 151, 153
Allen county; composition of soils and subsoils of.	355 to 358, 434
Analysis of, &c. See Composition of, &c.	
Analyses of coals, general results of	10
iron ores of Northeastern Kentucky, general results of.	10
soils, general remarks on	4
soils, method of	5, 40
Appendix to chemical report	155, 339
Ash analyses of Hemp and its products; clover, buckwheat, &c.. . . .	434 to 464
coal, composition of	48, 67
coal, phosphoric acid in.	67
of German millet; composition of the.	426, 428
of hemp and buckwheat plants, chemical examination of.	434 to 464
of Hungarian grass; composition of.	425, 429
percentage of coals as compared with their specific gravity	24, 105, 137, 157
Ashland Furnace , Boyd county, coal used at	166
pig iron, analysis of	25, 26
Band iron ore, black, from Jackson county; composition of	399, 400, 437
Barata sulphate in Owen county.	314
Baregine , in Grayson Spring sulphur waters	93
Barium and Strontian Chlorides in Glen Font brine.	297, 298
in Goose Creek brine.	232
Barren County ; composition of soils and subsoils of	358 to 363, 434
limestones, analyses of	16
marl and nitre earth	202, 203
Bath County ; composition of Ferruginous Magnesian Limestone of Chalybeate Springs in	369, 370
composition of saline waters in	371-374
composition of the Chalybeate Springs of.	268, 369
composition of the mineral waters of the Olympian Springs in	363, 366
facts about the mineral waters of the Olympian Springs in	353
iron ore, analysis of	16
iron ores and pig irons	198 to 202
Sulphur waters; composition of the	363 to 366
Bell County coals, soils, and subsoils.	203 to 215
Bellefont Furnace pig iron, analyses of	25, 217
Bessemer process; can phosphorus be removed by it?	197
Bittern water, composition and uses of, Goose Creek Salt-works.	232, 233
Glen Font Salt-works	297
Bituminous Shale	264, 265, 294, 295, 316, 336
Menifee county, analysis of	140
silicious petrification in, Lawrence county	283

- Black Band Iron Ore** from Jackson county; composition of 399, 400, 437
 Lawrence county 280, 281
 Muhlenburg county 141, 143
- "Black waxy"** soil from Collins county, Texas. 351, 435
- Block** coals of Indiana, analysis of 159
 iron ore of Carter county 222
- Blue Lick** (lower) Spring, in Nicholas county; composition of water from . 414, 415
 limestone, Cincinnati Group, of Campbell county, analysis of 42
- Boiler** crust and sediment, Franklin county, analysis of 73
- Boone** County clay 215, 216
 Furnace pig iron, analysis of 57
- Bored** wells of Fayette county, analyses of waters of. 73 to 75
 well of Franklin county, analysis of water of. 78
- Bourbon** County magnesian limestone 155
- Boyd** County coals, description and analyses of 20 to 23
 iron ores, analyses of 17
 soils and coals, analyses of 26, 166
- Branching** Chætetes, fossil, from Fayette county 383, 384
- Bracken** County soils and mudstone rock, analyses of 28
- Breathitt** County coals 218 to 222
- Breckinridge** County; composition and uses of Marly shale from . . . 374, 438
 red under clay, analysis of. 170
- Buckwheat** as a fertilizer for the hemp crop 462
 plants; experiments with. 432
- Buena Vista** Furnace pig iron, analysis of 25
- Buffalo** Furnace pig iron, analysis of 116
- Butler** County; composition of coal from 375, 436
 composition of Marly clay shale or Indurated clay from. 375, 376, 438
 iron ores, coals, and limestones, analyses of. 31
- Calcareous** spar of blue limestone, analysis of. 71
- Caldwell** County lead ore 34
- California** adobe soil, analyses of. 160
- Campbell** County marls, shales, clays, sand, soils, analyses of. 34
- Cannel** Coal 219, 220, 260, 263, 264, 265, 272 to 275, 291, 292, 295, 296, 315, 328
 Hunnewell, Greenup county, analyses of. 167
- Carter** County block iron ore and pig irons 222 to 224
 clays, coals, iron ores, limestones, pig irons, soils, analyses of. . . . 43 to 64, 166
- Centre** Furnace, in Trigg county; composition of pig iron from. . . . 421, 422, 437
- Chætetes**, fossil branching, from Fayette county 383, 384
- Chalk** rock, indurated, from Texas; composition of. 425
- Chalybeate** mineral water, Fulton county, analysis of 81
 Springs of Bath county; composition of the 368, 369
 Springs, in Bath county; composition of Ferruginous Magnesian Limestone
 of. 369, 370
 waters, Grayson county, analyses of 96
- Chemical Report** (Third) of the soils, coals, ores, iron furnace products, clays,
 marls, mineral waters, rocks, &c., of Kentucky, by Robert Peter, M. D.,
 &c., &c., Chemist to the Survey 347 to 438
- Christian** County coals, mineral waters and soils. 224 to 231
- Clay**, carbonaceous, Muhlenburg county 150
 County, Goose Creek salt waters, &c. 231 to 233

Clay , fire clay, of Muhlenburg county, analysis of	144
foot of grand chain, Illinois, analysis of	83
(potter's) from Franklin county; composition of	384, 438
from Ohio county; composition of	418, 438
German glass pot.	342, 344
(Indianaite)	344, 345
ironstone from Ohio county; composition of	416, 437
ironstone, Estill county.	243
Rockcastle county	321
shale, marly, or indurated clay from Butler county; composition of, 375, 376,	438
Clays	215, 239, 242, 243, 250 to 255, 287 to 289
Campbell county, analyses of	35
comparative table, composition of	45
of Kenton county, analyses of.	133
of the coal fields	15
fire clays of Carter county, analyses of.	43
fire clays of Greenup county, analyses of.	100
Cloverport Coal and Oil Company , their property, &c.	260, 263, 264
Clinton county marls, clay, and coal	233, 234
iron ore of Cumberland Gap.	197, 198, 339, 340
Coal , Cumberland mines, Clinton county	234
fibrous, Muhlenburg county, analysis of	150, 151
in subcarboniferous limestone formation, Grayson county	88
used at Ashland Furnace, Boyd county, analysis of	166
Coalton coal (No. 7)	46, 47
Coals , Bell county.	203 to 208
block coals from Indiana, analyses of.	159
Boyd county, analyses of	20 to 23
Boyd county, relation of specific gravity to weight of ash	24
Butler county, analyses of.	31, 375, 436
Carter county, analyses of.	46, 166
Christian county.	224, 225
Daviness county.	239 to 241
Edmonson county, analyses of.	65, 66
extremes of composition of, sulphur in.	191, 192
Floyd county	248 to 250
from Illinois, analyses of	157
from Indiana, analyses of.	158
from the State of Ohio, analyses of	155
from Winter's Gap, Tennessee	341
general results of analyses of	10
Grayson county, analyses of.	86 to 89, 250
Greenup county, analyses of	102, 167, 255, 256, 392, 393, 436
Hancock county	260 to 264
Harlan county.	264, 265
Hopkins county, analyses of	130, 266 to 269
Jackson county	272, 273
Johnson county	274, 275
Kentucky, table of composition of selected samples.	13
Kentucky, tables of average composition of	11

Coals, Kentucky, &c., tables of extremes of composition of	12
Lawrence county	135, 281, 282
Lee county	283 to 285
Madison county	289, 290, 408, 436
Magoffin county	290, 292
Martin county	292 to 294
McLean county	294, 295
Menifee county, analyses of	139, 300, 301
Morgan county	295, 296
Muhlenburg county	302, 303
Ohio, Indiana, and Illinois, average composition of	11
Ohio county, analyses of	152, 168, 305, 312
Owsley county	315, 316
Perry county	316 to 318
Pulaski county	318, 319
relation of ash proportion to specific gravity	192, 193, 207, 208, 222
Rockcastle county	320, 321
uncombined sulphur and lime sulphate in	151
Wolfe county	327 to 328
Coke of Coalton coal	49
used at Airdrie Furnace, Muhlenburg county	147
Collins County, Texas; "black waxy" soil from	351, 435
Texas; composition of soil from	424, 435
Composition and uses of Marly shale from Breckinridge county.	374, 438
of black band iron ore from Jackson county	399, 400, 437
of clays from Ohio county	418, 438
of clay ironstone from Ohio county	416, 437
of coal from Butler county	375, 436
of coals from Greenup county	392, 393, 436
of coal from Madison county	408, 436
of indurated chalk rock from Texas	425
of limestone from Mercer county	413, 414
of limestones from Ohio county	417
of Limonite iron ore from Trigg county	420, 421, 436
of Limonite ores (iron ores) from Lyon county	407, 436
of Marly clay shale or Indurated clay from Butler county	355, 376, 438
of material, soils, subsoils, and under-clays from Grant county	384 to 390, 434
of mineral water from Jessamine county	400 to 402
of mineral water from Lincoln county	402
of mineral water (sulphur water) from Madison county	408
of mineral water from Nicholas county	414, 415
of mineral water from Warren county	422, 423
of phosphatic limestones from Fayette county	380 to 383
of pig irons from Trigg county	421, 422, 437
of potter's clay from Franklin county	384, 438
of red bud soil from Madison county	409, 435
of Saline waters in Bath county	371 to 374
of soils, extremes of variation in	351
of soils and subsoils of Allen county	355 to 358, 434
of soils and subsoils of Barren county	358, 363, 434
of soils of Fayette county	378 to 380, 434

Composition of soils from Hardin county	393 to 397, 435
of soils from Hopkins county	398, 399, 435
of soils and subsoils from Logan county	403 to 407, 435
of soils and under-clay from McCracken county.	410, 411, 435
of soils and under-clay of Meade county.	411, 413, 435
of soils from Oldham county	419, 420, 435
of soils from Texas.	423, 424, 435
of the Bath county Sulphur waters	363, 366
of the Chalybeate Springs of Bath county	368, 369
of the water of the "Kaiser-quelle" at Aix-la-Chapelle.	366, 367
of virgin soil and subsoil from Grayson county.	390, 391, 434, 435
of well water from Fayette county.	376 to 378
Crab Orchard Salts	287, 288
Crown Ore , (iron) Carter county, analysis of	53
Daviess County mineral waters, soils, clays, and coals	234 to 241
Dyestone Ore of Tennessee.	339, 340
Edmonson County iron ores, coals, and cast iron	64 to 68, 162
iron ores and clays	241 to 243
Estill County iron ores and pig irons	243 to 245
Experiments with Hungarian grass, German millet, and buckwheat	245, 425
Extremes of variations in composition of soils	151
Fayette County ; composition of soils of	68 to 75, 378, 380, 434
composition of phosphatic limestones and soils from.	245 to 248, 380 to 383
composition of well water from	376, 378
fossil branching Chætetes from	383, 384
fossil shells from	383, 384
Ferruginous Magnesian Limestone , of Chalybeate Springs, in Bath county; com- position of.	369, 370
Fertilizers , mineral and atmospheric elements	9
Fibrous Coal	130, 131
Fire Clay , German glass pot.	342 to 344
of Carter county, analyses of.	43
of Greenup county, analyses of	100
of Muhlenburg county, analysis of.	144
Floyd County Coals	248 to 250
Foxden iron ore, Carter county, analysis of	50, 51
Fossil branching Chætetes from Fayette county	383, 384
shells from Fayette county	383, 384
Franklin County ; composition of potter's clay from	384, 438
marly shales, waters, &c.	75
Fulton County , soil, mineral water, clay, silicious deposits, sandstones, &c.	80 to 83
Galena from Owen county.	313, 314
in Henry county.	129
(lead ore) from Harrison county.	397, 398
of Caldwell county, analysis of	174
German glass pot fire clay	342 to 344
(iron) ore, Carter county, analysis of, &c.	52
millet.	353 to 355
millet; composition of the ashes of	426 to 428
Glairine in Grayson Springs sulphur waters.	94
Glen Font Salt Works , Meade county	296 to 300

Goose Creek Salt Works, Clay county.	231 to 233
Grayson County coal, clay, and iron ore.	250 to 255
iron ores, marly shales, sandstone, coals, waters, and soils.	83 to 100, 163
Springs mineral waters, analyses of	89 to 97
Greenup County clays, coals, limestones, iron ores, pig irons, and soils,	100 to 118,
	167
Grant County; composition of material, soils, subsoils, and under-clays from,	384 to
	390, 434
Grass, Hungarian.	353 to 355
composition of the ashes of	425 to 429
Grayson County, Texas; composition of soils from	423, 424, 435
composition of virgin soil and subsoil from.	390, 391, 434, 435
Greenup County; composition of coals from	392, 393, 436
coals, pig irons, iron furnace slags, and soils	255 to 260
Grey lime ore	107
Hancock County coals.	260 to 264
Hardin County; composition of soils from.	117 to 129, 393 to 397, 435
Hard limestone water of Fayette county for irrigation, &c.	73
Harlan County coals.	264, 265
Harrison County; lead ore (galena) from.	397, 398
Hematite iron ore, red, Lawrence county.	137
Hemp culture, influence on soil, &c.	69
and buckwheat plants, chemical examination of the ashes of	439 to 464
culture in Kentucky	441, 442, 443, 449, 451, 456
dew-rotting and water-rotting, changes which occur in.	451, 453
Henderson's process for the purification of iron	195 to 197
Henry County galena (lead ore) and marly shale.	129
metallic lead and limestone	265, 266
Hocking Valley (Ohio) coals.	156
Hopkins County coals and ocherous iron ores	130
coals and soils	266 to 272
composition of soils from.	398, 399, 435
Horsley Bank iron ores, Carter county.	51, 52
Hungarian Grass.	353 to 355
composition of the ashes of.	425 to 429
microscopic photographs of	428
Hunnell Furnace pig iron	116, 256 to 258
Indianaite of E. T. Cox.	344, 345
Indiana coals, analyses of	158
Indurated chalk rock from Texas; composition of.	425
clay, or marly clay shale, from Butler county; composition of	375, 376, 438
Illinois clay, Post Tertiary, analysis of	83
coals, analyses of	157
Iron furnace slag, Raccoon Furnace	258
Henderson's process for purification of.	195 to 197
Iron Hill, Carter county.	223, 224
Iron Hills Furnace, flux limestone, analysis of	56
Furnace, pig iron, analysis of	57
Iron Ore, black band, from Jackson county; composition of.	399, 400, 437
(Clay ironstone) from Ohio county; composition of	416, 437
Clinton, of Cumberland Gap	197, 198

Iron Ore , limonite, from Trigg county; composition of	420, 421, 436
limonite, of Clinton Group, Bath county, analysis of	16
of Grayson county	83, 163, 254
Iron Ores , black band, Lawrence county	280, 281
carbonates	216, 217
general results of analyses of	10
(Limonite ores) from Lyon county; composition of	407, 436
Limonite of Bath county	198 to 200
of Boyd county	17, 216, 217
of Butler county, analyses of	31
of Carter county, analyses of	49
of Edmonson county	64, 162, 241, 242
of Estill county	243, 244
of Greenup county, analyses of	106
of Kentucky, extremes of proportion of iron and phosphorus in.	193
of Lyon county	138
of Muhlenburg county, analyses of	143
ochreous, Hopkins county, analyses of	131
Iron, Pig , extremes of composition of	198
of Bath county.	200 to 202
of Greenup county.	256 to 258
of Kentucky, average composition of.	15
Irons, Pig	198, 200 to 202, 217, 218, 256 to 258
Jackson County coals	272, 273
composition of black band iron ore from.	399, 400, 437
Jessamine County ; composition of mineral water from	400 to 402
mineral water	273, 274
Johnson County coals.	274, 275
"Kaiser-quelle" at Aix-la-Chapelle; composition of the.	366, 367
Kaolin , Indiana.	344, 345
Kenton County silicious grit, clays, marly shales, and limestones.	132 to 135
Furnace, limestone flux used at	105
Furnace, pig iron, analysis of	116
Kentucky natural resources.	190, 191
Kidney iron ore.	111, 112
Knox County ferruginous limestones and soils	275 to 278
Lambert iron ore.	52
Laurel County soils	278 to 280
Laurel Furnace pig iron.	257, 258
Lawrence County black band iron ores, coals, limonite ores, &c.	280 to 283
coals and iron ore.	135 to 137
Lead , metallic, Henry county	265
ore (galena) from Harrison county	397, 398
ore (galena) Royal mines, Livingston county	137
ore of Caldwell county, analysis of.	34
ore of Henry county	129
Lee County coals.	283, 284
Leitchfield marls.	250, 255
Lewis County soils.	287, 288
Lime of Fayette county (blue limestone), analysis of.	71
(quick lime), of Montgomery county.	141
	471

Lime, use of, on soils	70, 71
Limestone (blue argillaceous), Kenton county, analysis of	134
blue, of Campbell county, analysis of	42
Ferruginous, Knox county	275, 276
Ferruginous Magnesian, of Chalybeate Springs, in Bath county; composition of.	369, 370
Lower Silurian, Henry county.	266
Kenton county, useful in agriculture.	135
magnesian, Bourbon county, analysis of	155
Muhlenburg county, used at Airdrie Furnace	144
ores, limonite ores	108, 112
ores of Carter county, analyses of	49, 50
phosphatic, of Fayette county.	198
from Mercer county; composition of.	413, 414
phosphatic, from Fayette county; composition of.	380 to 383
Limestones of Carter county, analyses of.	56
of Greenup county, analysis of	105
upper subcarboniferous oölitic and lithographic.	16
from Ohio county; composition of.	417
Limonite iron ores, Bath county.	198 to 200
iron ores, Edmonson county.	241, 242
iron ores, Estill county	243, 244
iron ore, Grayson county	254
iron ores, Lawrence county	282, 283
iron ore, Menifee county	301
iron ore, Ohio county	312, 313
ores (iron ores) from Lyon county; composition of	407, 436
iron ore from Trigg county; composition of.	420, 421, 436
Lincoln County clay and Crab Orchard Salts.	287, 288
composition of mineral water from.	402
Lithographic stone	16
Livingston County galena (lead ore)	137
Logan County ; composition of soils and subsoils from.	403 to 407, 435
Lower Block iron ores.	106, 107, 109, 110, 112
Carter county, analyses of.	50, 51, 53
Lower Blue Lick Spring , in Nicholas county; composition of water from the,	414, 415
facts about the mineral waters of the	353
Lyon County ; composition of Limonite ores (iron ores) from	407, 436
iron ores, &c.	138, 161
Madison County ; composition of coal from.	408, 436
clays and coals.	288 to 290
composition of mineral water (sulphur water) from	408
composition of red bud soil from.	409, 435
Magoffin County coals.	290 to 292
Main Block iron ore, Carter county, analyses of.	52, 53, 54
ore	107, 110, 111
Marl , Barren county.	202
Marls and marly shales, of Campbell county, analyses of.	34, 42
marly shales, &c., alkalies and phosphoric acid in	14, 24, 34, 75, 84
or shales of the Chester Group ("Leitchfield marls").	250 to 255

Marly Clay , Clinton county	233
of Grayson county and their uses	250 to 255
shale or indurated clay from Butler county; composition of	375, 376, 438
Marly Shale from Breckinridge county; composition and uses of	374, 438
of Boyd county	24
of Franklin county, analysis of	75
of Grayson county, analyses of	84
of Henry county, analysis of	129
of Kenton county, analyses of	134
Martin County coals	292 to 294
Material , soils, subsoils, and under-clays from Grant county; composition of, 384 to	390, 434
McCracken County ; composition of soils and under-clay from	410, 411, 435
McLean County bituminous shale and coal	294, 295
Meade County ; composition of soils and under-clay of	411 to 413, 435
Menifee County coals and bituminous shale	139
coals and iron ores	300, 301
Mercer County ; composition of Limestone from	413, 414
Metallic iron (Meteoric), Rockcastle county	322
Microscopic photographs of Hungarian grass	428
Millet, German	353 to 355
composition of the ashes of	426 to 428
Mineral Paint , Franklin county	75
Grayson county	85
Hopkins county	131
Mineral Water from Jessamine county; composition of	400, 402
from Lincoln county; composition of	402
chalybeate, Fulton county, analysis of	81
chalybeate, Pulaski county	319
of Christian county, salt sulphur, Hopkinsville	225, 226
sulphur, Fleetwood farm, Franklin county	79
(sulphur water) from Madison county; composition of	408
from Nicholas county; composition of	414, 415
from Warren county; composition of	422, 423
sulphur, Webster county	323
Mineral Waters , chalybeate and alum, Daviess county	234 to 236
chalybeate, Webster county	323
chalybeate, Whitley county	325
of Grayson Springs	89 to 97
of Kentucky, general remarks on	15
of the Lower Blue Lick Springs, in Nicholas county, facts about the	353
salt sulphur, at Nicholasville, Jessamine county	273, 274
sulphur, &c., Daviess county	236, 237
of the Olympian Springs, in Bath county; composition of	363, 366
of the Olympian Springs, in Bath county: facts about the	353
Montgomery County quicklime, analysis of	141
Morgan County coals	295, 296
Mt. Savage Furnace limestone, used as a flux at	56
pig iron, analysis of	57, 223, 224
Mudstone , silicious, of Bracken county, analysis of	30
Muhlenburg County coals and soils	302, 305
	473

Muhlenburg County iron ores, limestone, clay, pig iron, coals &c.	141 to 152
Nicholas County ; composition of mineral water from	414, 415
facts about the mineral waters of the Lower Blue Lick Springs in	353
Nitrate in soils	40
Nitre Earth of Barren county	202
Nitrogen , how supplied to plants	189
Nobel's apparatus for silt analysis of soils.	40
Nolin Furnace (old), ore and pig iron from	162, 163
Ochre , brownish yellow, Hopkins county	131, 132
Ohio County coals and iron ores.	305 to 313
coals and soils.	152, 153, 168
composition of clays from	418, 438
composition of clay ironstone from	416, 437
composition of limestones from	417
Ohio (State) coals, analyses of	155
Oldham County ; composition of soils from	419, 420, 435
Olympian Springs , in Bath county; composition of the mineral waters of the.	363 to 366
facts about the mineral waters of the	353
Ore , black band iron, from Jackson county; composition of	399, 400, 437
limonite (iron) from Lyon county; composition of.	407, 436
Owen County galena and barata sulphate	313, 314
Owsley County coals	315, 316
Panicum Germanicum ; composition of the ashes of	425 to 429
Plants , action of, on rock materials	431, 433
buckwheat; experiments with	432
Peach Orchard coal	281, 282
Pennsylvania Furnace pig iron.	256 to 258
Perry County coals	316 to 318
Peter, Robert, M. D., &c. , chemical examination of the ashes of hemp and buckwheat plants.	439, 464
Third Chemical Report of the soils, coals, ores, iron furnace products, clays, marls, mineral waters, rocks, &c., of Kentucky	349 to 438
Sixth Chemical Report.	181 to 346
and John H. Talbutt, Fifth Chemical Report	1 to 180
Phosphatic limestone, Fayette county	198, 245, 380 to 383
Phosphoric Acid in coal ash.	67
Phosphorus in iron, influence of, and modes of its removal.	193 to 195
in iron furnace cinder	194, 258
Pig Iron , Airdrie Furnace, Muhlenburg county	145
average composition of Kentucky.	15
extremes of composition of	198
from Clinton ore.	341, 342
from Trigg county; composition of.	421, 422, 437
of Bath county.	200 to 202
of Boyd county, analyses of	25, 217, 218
of Carter county	223, 224
Carter county furnaces, analyses of	57
of Estill county	244, 245
of Greenup county, analyses of	116, 256 to 258
Old Baker Furnace, Edmonson county.	67

Pig Iron , Old Nolin Furnace, Edmonson county, analysis of	162
Potato Knob iron ore, Carter county	52
Potter's Clay from Franklin county; composition of	384, 438
Pulaski County coals and chalybeate water	318, 319
Raccoon Furnace , flux used at	105
slag	258
Red-bud soil from Madison county; composition of	409, 435
Red limestone (iron) ore, Carter county, analysis of	54
River Furnace pig irons	244, 245
Report (Chemical), Third, of the soils, coals, ores, iron furnace products, clays, marls, mineral waters, rocks, &c., of Kentucky, by Robert Peter, M. D., &c., &c., Chemist to the Survey	349 to 458
Rockcastle Chalybeate Springs, Pulaski county	319, 320
county coals, clay and metallic iron	321 to 323
Rock Material ; action of plants on	431 to 433
Rough Ore (iron), Carter county, analysis of	53, 111
Rye as a fertilizer for hemp crop	459, 460
Saline Waters in Bath county; composition of	371 to 374
Salt Sulphur Water from Nicholas county; composition of	414, 415
Salt Water , salt, bittern, &c., Glen Font salt works	296 to 310
Salt Works , Goose creek, Clay county	231 to 233
Sandstone of Grayson county, analysis of	86
(soft), Fulton county, analysis of	82
Shale , bituminous, Menifee county	140
marly, in Breckinridge county; uses and composition of	374, 438
Shells , fossil, from Fayette county	383, 384
Silicious concretions, Fulton county	81
deposits of Fulton county, remarks on	82
grits, Kenton county, analyses of	132
mudstone of Bracken county, analysis of	30
Silt , analyses of soils	40
Silver in the lead ore of Caldwell county	34
Soil , adobé, of California, analysis of	160
analyses, general remarks on	4, 5
"black waxy" from Collins county, Texas	351, 435
comparative exhaustion of, by hemp, corn, wheat, and tobacco	454, 455
how to enrich it for hemp culture	460, 461
insoluble silicates of	187, 188
its fertility, as influenced by dry seasons	449
organic matters of, influence of	187
red-bud, from Madison county; composition of	409, 435
virgin, and subsoil from Grayson county; composition of, 97, 390, 391, 434, 435	
Whitley county	327
Soils and subsoils of Allen county; composition of	355 to 358, 434
and subsoils of Barren county; composition of	358 to 363, 434
and subsoils of Logan county; composition of	403 to 407, 435
subsoils, material, and under-clays from Grant county; composition of, 384 to 390, 434	
and under-clay of Meade county; composition of	411 to 413, 435
and under-clay from McCracken county; composition of	410, 411, 435
agricultural capabilities of, ascertained by analyses	41

Soils , analyses of silicious residue and sand of	40, 70
causes of exhaustion of, in hemp crop	456
comparative analyses of old and new	8, 41, 64
exhaustion by cropping shown by analysis.	8, 41, 64
extremes of variations in composition of.	351
&c., of Bell county.	208 to 215
of Boyd county, analyses of.	26
of Bracken county, analyses of	28
of Campbell county, analyses of.	36
of Carter county, analyses of	58
of Christian county	226 to 231
of Daviess county	237 to 239
of Fayette county, composition of.	68, 446 to 448, 378 to 380, 434
of Fulton, analyses of.	80
of Greenup county, analyses of	117, 259, 260
of Hardin county, analyses of.	117 to 129, 393 to 397, 435
from Hopkins county, composition of	269 to 272, 398, 399, 435
of Kentucky, limits of variation of composition of	185
of Knox county	276, 278
of Laurel county.	278 to 280
of Lewis county.	285, 287
of Muhlenburg county	303, 304
of Ohio county, analyses of	153
from Oldham county, composition of.	419, 420, 435
from Texas, composition of	423, 424, 435
of Webster county.	324, 325
rich and poor, characteristics of	185, 186
silt, analysis of.	40
Specific gravity of coals compared with ash proportions, 24, 192, 193, 207, 208, 222	
Subsoil , influence of subsoiling, trenching	186, 187, 231
soils, material and under-clays from Grant county; composition of, 384 to 390,	434
and virgin soil of Grayson county; composition of	390, 391, 434, 435
Sulphur in Coals	191, 192, 206, 207
determination of.	14, 24
not all injurious in iron smelting	160
Sulphur Waters of Bath county; composition of the.	363 to 366
Fleetwood farm, Franklin county, analysis of.	79
Grayson county, analyses of.	89 to 96
water in Madison county, composition of.	408
from Warren county, composition of.	422, 423
Sulphur , uncombined, in coals.	151
Suwanee Furnace iron ores, analyses of.	138
Table of ash analyses of dew-rotted hemp	452
of ash analyses of the fibre of dew-rotted hemp and hemp-herds.	454
of the ash composition of buckwheat	462
of composition of clays.	180
of the ash constituents of clover and hemp.	461
of the ash constituents of hemp plants.	447
of the ash constituents of the leaves, roots, and stems of hemp.	449
of the entire ash of hemp plants	446

Table of composition of clay ironstone ores	175, 336
of composition of coals	176 to 178, 332 to 335
composition of iron ores (limonites)	173, 174, 335, 336
of the average composition of Kentucky coals	11
of composition of limestones	172
of composition of marls, marly shales, silicious concretions, &c.	179, 338
of composition of pig irons	181, 337
of selected Kentucky coals	13
of composition of soils, &c., &c.	170 to 172, 330, 331
of the extremes in the composition of coals of Kentucky	12
Talbutt, John H. , chemical assistant	1, 3
Texas ; "black waxy" soil from Collins county, in	351, 435
composition of indurated chalk rock from	425
composition of soils from	423, 424, 435
Third Chemical Report of the soils, coals, ores, iron furnace products, clays, marls, mineral waters, rocks, &c., of Kentucky, by Robert Peter, M. D., &c., &c., Chemist to the Survey	347 to 438
Trigg County ; composition of limonite iron ore from	420, 421, 436
composition of pig irons from	421, 422, 437
Trigg Furnace , in Trigg county; composition of pig iron from	421, 424, 437
Under-clay , red, of Breckinridge county, analysis of	30
material, soils, and subsoils of Grant county; composition of	384 to 390, 434
and soils from McCracken county; composition of	410, 411, 435
and soils of Meade county; composition of	411 to 413, 435
Uses and composition of marly shale from Breckinridge county	374, 438
Variations , extremes of, in composition of soils	351
Virgin soil and subsoil of Grayson county; composition of	390, 391, 434, 435
Warren County ; composition of mineral water from	422, 423
Well Water from Fayette county; composition of	368 to 378
Water from a bored well in Fayette county; composition of	376 to 378
mineral, from Jessamine county; composition of	400 to 402
mineral, from Lincoln county; composition of	402
mineral (sulphur), from Madison county; composition of	408
mineral (salt sulphur), from Nicholas county; composition of	414, 415
from interior of iron ore geode, analysis of	161
influence of on the soil	186
of Grayson Springs, analyses of	89 to 97
of Franklin county, analyses of	76
of Fayette county, analyses of	72 to 75
Webster County mineral waters and soils	323, 324, 325
Whitley County mineral waters, bituminous shale, and soil	325 to 327
Wolfe County coals, &c.	327 to 329
Yellow Kidney iron ore, Carter county, analysis of	54