REPORT

ON THE

CULTIVATION AND MANUFACTURE OF INDIGO IN BENGAL

(For the Indigo Defence Association, Limited).

BY

CHRIST^R. RAWSON, F.I.C.

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BRADFORD, *March*, 1899.

To the Directors of the Indigo Defence Association, Limited.

GENTLEMEN,

In presenting my first Annual Report, I regret the delay which has occurred, but the work involved in the analyses and experiments has been much greater than I had anticipated. Even now the report is not so complete as I should like it to have been.

As will be expected the report deals chiefly with my visit to India, the results of experiments made in Behar, and of analyses of indigo, soils, plants, &c., made in England since my return. I have analysed a great many samples taken at various times during my stay in Behar, but, unfortunately, on account of the heavy rains and floods in September these samples were not as representative as they might have been. Nevertheless, the work has been full of interest, and a considerable amount of valuable information has been gained. I fully believe that the **Prospects.** cost of production of indigo in Behar can be materially reduced, and also that the quality in numerous cases may be greatly improved.

I left London on the 25th May, 1898, and reached Mozufferpore on the 20th June.

As stated in my first Indian Report to the Behar Planters' **Visit to factories.** Association of the 14th July, I spent the first two or three weeks visiting various indigo factories (chiefly in the Champarun district), and thus gained a general knowledge of the present mode of manufacturing indigo. During this period a chemical laboratory was being erected in the compound of the Planters' Club, Mozufferpore, but it was about the end of July before everything was in working order. Some of the apparatus and chemicals did not arrive until later. I left Mozufferpore on the 3rd October, so that the time available for chemical work in

Time available in India for experiments. India was little more than eight weeks. Since my return to England on the 24th October, 1898, my time has been chiefly devoted to the analysis of samples brought from Behar.

Cultivation of plant and manufacture of indigo. In connection with my mission to India, there are two distinct problems which present themselves for investigation; one requiring a study of the best methods of cultivation of the plant, and the other a research into the best means of obtain ing a maximum yield of dye from a given weight of plant.

In all experiments and observations made in indigo concerns it is important that this distinction should be clearly held in view. All factories keep a record (more or less comprehensive) of the work done each day during "Mahai," but unfortunately, from an investigator's point of view, these records seldom show whether the variable results frequently obtained are to be attributed to a difference in the quality of the plant, or to certain changes taking place during the process of manufacture.

I.—Cultivation of Indigo.

Cultivation. Perhaps in the first place it will be best to take a view of the agricultural problem. It is well known among indigo planters that some lands furnish much better crops than others, though it does not necessarily follow that the heaviest crop yields the greatest amount of indigo. As far as I have been able to ascertain very little has been done in experimenting with artificial manures, and where experiments have been made they have not been carried out in a scientific manner. I am firmly of opinion that in the cultivation of the indigo plant there is much scope for improvement. If, however, the application of artificial manures is found to be too costly for the benefits obtained, the cultivation of the plant should be restricted as far as possible to such land as can be worked remuneratively, that is land which has been shown by analysis or found by experience to be capable of giving good results. The investigation would be much simplified if some ready means were known of determining the amount of the colour-giving principle "indican" in indigo leaves. At present, however, this is not possible. I have made analyses of twelve samples of indigo leaves, and one sample of the stems. The samples vary greatly in their composition, and I shall refer to this matter later, but for the present purpose will merely cite the mean results of the twelve samples. The following table (No. 1) shows the compo-

Scope for improvement.

Analysis of indigo plant.

TABLE I.—Analysis of Indigo Plant.

	Air-dried.		Green Plant.	
	Leaves.	Stems.	Leaves.	Stems.
Water	10·42	9·75	75·00	75·00
*Nitrogenous matters	29·37	5·94	8·19	1·65
Oil, &c., soluble in ether ...	3·85	1·05	1·07	·29
Woody fibre	11·07	47·50	3·09	13·16
Carbo-hydrates and other organic matter ...	33·29	31·01	9·30	8·60
†Mineral matter (ash)	12·00	4·75	3·35	1·30
	100·00	100·00	100·00	100·00
Matter soluble in water—				
Organic	25·05	9·05	6·99	2·51
Mineral	7·55	2·65	2·11	·73
*Containing nitrogen	4·64	·94	1·293	·260
†Mineral matter containing—				
Silica	·628	·051	·175	·013
Phosphoric acid	·916	·344	·255	·095
Sulphuric acid	·296	·074	·084	·021
Carbonic acid, &c. ...	2·885	1·163	·806	·323
Chlorine	·050	·074	·014	·021
Oxide of iron & alumina.	·086	·020	·024	·006
Manganese oxide	·040	·025	·011	·008
Lime	3·591	1·275	1·002	·353
Magnesia	1·298	·164	·362	·045
Potash	2·210	1·460	·616	·404

TABLE II.—Composition of Ash in 100 parts.

	Leaves.	Stems.
Silica	5·23	1·10
Phosphoric acid	7·64	7·40
Sulphuric acid	2·46	1·58
Carbonic acid, &c.	24·05	25·03
Chlorine	·41	1·58
Oxide of iron and alumina	·71	·43
Manganese oxide	·33	·53
Lime	29·94	27·43
Magnesia	10·82	3·50
Potash	18·41	31·42
	100·00	100·00

sition of the plant as analysed (air-dried), and also calculated on the green plant containing (as it does on an average) 75 per cent. of water. Table II. shows the composition of the mineral matter in 100 parts.

Nitrogenous matter.

The "nitrogenous matter" in the above table is calculated from the percentage of nitrogen found in the samples, on the assumption that it is all of an albuminous character, though there are other forms of nitrogenous bodies present. The only other analysis of indigo plant which I have been able to find is one made by E. C. Schrottky, and which appears in a pamphlet on "Indigo and Indigo Manufacture," published in 1879. The results, however, are quite at variance with those of my own. For example, Schrottky found the sun-dried plant to contain 75·45 per cent. of woody fibre. The highest result I obtained with leaves was 12·30 per cent., whilst even the stems taken alone did not contain more than 47½ per cent. The total amount of organic matters exclusive of woody fibre in Schrottky's analysis is only 7·6 per cent. The lowest result which I have obtained was 62 per cent. in leaves and 38 per cent. in stems. Regarding the mineral matter Schrottky found 100 parts of ash to contain as much as 26·34 per cent. silica. The highest amount of silica I found was 8·75 per cent. in leaves. The stems contain much less silica than the leaves. The plant examined by Schrottky was grown near Calcutta; but, according to the analysis quoted, its composition was entirely different to that of any sample of indigo plant which I have examined.

Referring to my own analysis as given above (Table I.), it will be seen that the indigo plant abstracts a considerable amount of mineral matter from the soil, and that the leaves are rich in nitrogen. In order to estimate the amount of matter taken from the soil by a crop of indigo it will be necessary in the first instance to determine the relative amount of leaf and stem constituting the plant. I made twenty determinations of various samples of plant, and found, as might be expected, very great variations in this respect. The mean results gave in round numbers 40 per cent. leaf and 60 per cent. stem. The highest percentage of leaf in the twenty tests was 56 and the lowest was 33. I have reason to believe, however, from my own observations, that the amount of leaf frequently falls below 33 per cent. of the whole plant. As the stems contain practically no colour-yielding principle, and seeing that the whole plant is put into the

Relative amount of leaf and stem in plant.

No colour yielded by stems.

steeping vat, it is evident that this great possible variation in the relative amount of leaf and stem accounts in a great measure for the different results frequently obtained in the manufacture of the dye. I shall refer to this question later. For our purpose at present we may consider the plant on an average to contain 40 per cent. of leaf. The more important constituents in the *whole* green plant (containing 75 per cent. water) will therefore be as follows :—

TABLE III.—SHOWING MORE IMPORTANT CONSTITUENTS IN 100 PARTS OF WHOLE GREEN PLANT.

Nitrogenous matters	4·266 per cent.
Containing nitrogen	0·673 ,,
Mineral matter (ash)	2·114 ,,
Containing—	
Phosphoric Acid	0·159 ,,
Lime	0·613 ,,
Magnesia	0·172 ,,
Potash	0·489 ,,

Taking the results furnished by twelve factories in Champarun, extending over a period of four or five years, I find that one bigha of land yields on an average 90 maunds of green plant. The variations, however, are very great; the maximum being 165 and the minimum 50, so that 90 maunds can only be considered an approximate average. According to the above analyses a crop of 90 maunds per bigha would abstract from the soil the following constituents. In order to avoid any misunderstanding regarding the term "bigha," as it appears to be a variable quantity, I also give in the same table the number of pounds per acre. In this calculation one bigha (Champarun) is taken as being equivalent to 1⅓ acres.

Amount of crop per bigha.

Mineral constituents withdrawn from soil.

TABLE IV.—MINERAL MATTER WITHDRAWN FROM SOIL BY AVERAGE INDIGO CROP.

	Seers per Bigha.	Lbs. per Acre.
Total mineral matter	76·10	117·57
Phosphoric acid	5·72	8·84
Lime	22·07	34·10
Magnesia	6·20	9·70
Potash	17·60	27·20

Nitrogen in crop.

The plant from a bigha of land would also carry with it 24·23 seers of nitrogen, or 37·43lb. from an acre. Unlike the mineral constituents, however, this large amount of nitrogen is probably not all derived directly from the soil, but in a great measure from the atmosphere. The indigo plant (*Indigofera tinctoria*) belongs to the Natural Order *Leguminosæ*. These plants, or many of them, have the power of fixing and utilising atmospheric nitrogen through the medium of the nodules which form on their roots. With some kinds of leguminous plants the fixation of nitrogen takes place to such an extent that the application of nitrogenous fertilisers produces no increase in the crop. In the case of indigo, however, although no doubt atmospheric nitrogen is fixed, I am of opinion that with lands poor in nitrogen the application of nitrogenous manures would be decidedly beneficial. It is well known that the refuse plant known as *seet* is a valuable fertiliser for indigo, and this material contains a high percentage of nitrogen. I have analysed only one sample of *seet*, but found it to contain a higher percentage of nitrogen than the original plant; showing that the matter removed by steeping in water was less nitrogenous than the insoluble portion.

Fixation of atmospheric nitrogen.

Refuse plant or "seet."

TABLE V.—Analysis of Refuse Plant "Seet."

(Leaves Air-dried).

Water	10·05	
*Nitrogenous matter	35·44	
Oil, &c., soluble in ether	2·35	
Woody fibre	15·15	
Carbo-hydrates, &c.	28·41	
Mineral matter (ash)	8·60	
	100·00	
Matter soluble in water—		
Organic		7·50 per cent.
Mineral		2·80 „
*Containing nitrogen		5·60 „

Value of "seet" as a fertiliser.

The original plant contained 4·80 per cent. of nitrogen. It will be observed (Table VI.) that the refuse plant contains in addition to nitrogen a considerable amount of potash and phosphoric acid. In fact, it contains all that is required for the growth of a new crop. The beneficial effects resulting from the application of "seet" is probably due to the presence of all these constituents, but it remains for future experiments to determine which is the

TABLE VI.—COMPOSITION OF ASH OF REFUSE PLANT (LEAVES).

	In 100 parts of air-dried "seet" (leaves).	In 100 parts of Ash of Refuse Leaves.
Silica	0·784	9·12
Phosphoric acid	0·840	9·76
Sulphuric acid	0·175	2·03
Carbonic acid, &c....	1·624	18·88
Chlorine	0·080	·93
Oxide of iron and alumina	0·148	1·73
Manganese oxide	0·084	·97
Lime	2·730	31·76
Magnesia...	0·735	8·55
Potash	1·400	16·27

most valuable. The "seet" is usually applied to land in the immediate neighbourhood of the factories, and, in my opinion, it is frequently spread too thickly on the land. I am aware that the cost of cartage is an important item of expenditure, but it would be far preferable to spread the "seet" over a much greater area than is done at present. In my opinion, there is a great field for useful research in the application of suitable fertilisers for growing indigo. The experiments, to be of any use, must be carried out in a thoroughly systematic manner on comparatively small plots. As there is a considerable variation in the soil in different parts of Behar, it would be well to select three or four stations for carrying out these agricultural experiments. I have analysed about forty samples of soil from Behar. All the samples contain an abundant supply of potash, and this ingredient is certainly required for the growth of the indigo plant. The amount of phosphoric acid varies considerably, and, on the whole, is present in sufficient quantities. As regards the important constituent nitrogen, Dr. Voelcker states, in his report on "Indian Agriculture," 1893, that most of the soils of India are deficient, and this view is confirmed by the analyses of a great number of soils by Dr. J. W. Leather, published in the *Agricultural Ledger*, 1898. My own analyses also show that the soils of Behar form no exception in this respect to the soils of other parts of India, although some

Application of "seet."

Experiments with fertilisers.

Analysis of soils.

Potash.

Phosphoric acid.

Nitrogen.

contain much more than others. Notwithstanding the fact that indigo is a leguminous plant, and possibly derives much of its nitrogen indirectly from the atmosphere, yet, on account of the large amount of nitrogen which the plant requires for its growth, it is highly probable that beneficial results would accrue from the application of nitrogenous manures. It is well also to bear in mind that indigotin itself, the chief colouring matter of indigo, is a nitrogenous compound, and possibly the formation of the glucoside from which indigo is derived may be retarded by a lack of nitrogenous food. Indigotin ($C_{16}H_{10}N_2O_2$) contains 10·68 per cent. of nitrogen. As the green plant contains ·673 per cent. of nitrogen, it is evident that only a very small proportion of this element can exist in the form of a colour-giving principle. It is chiefly present as legumin or vegetable casein.

Much Nitrogen in indigo.

Lime.

The samples of soil vary greatly as regards the amount of lime present, and some contain but a small quantity, though in none can there be said to be a deficiency. It is possible, however, that some soils in Behar could be improved by the application of lime.

Tables VII. and VIIA. (pp. 11 and 12) show the detailed analyses of a number of soils. In most cases the figures given are the mean results of two analyses of the surface and sub-soil respectively. As these exhibited very little difference I thought it would only complicate an already lengthy table by inserting the results separately. In future it would be best to take samples of sub-soil at a greater depth—say 3 feet. Referring to the soils from Seeraha concern, as one would expect to find, there is a considerable difference between the composition of Seeraha light sandy soil and Seeraha heavy clay soil. The former contains much more lime and less sand than the latter. The two corresponding soils from Pareywah do not exhibit this difference. It would almost appear that some mistake had been made in sampling, and I should be glad to examine fresh samples of these two soils. The tables also show the quality of indigo produced. The figures in many cases are the results of individual tests and do not show the average of the whole season.

Analyses of plants.

In connection with the analyses of soils, perhaps it will be well to consider the analyses of a few samples of plants in detail, principally with a view of comparing their mineral constituents. Table VIII. shows the general composition of nine samples of plant-leaf (air-dried), and Table IX. shows the composition of the mineral matter or ash in 100 parts.

TABLE VII.—Composition of Soils.

Date received (1898).	25th Aug.	25th Aug.	1st Sept.	28th July.	1st Sept.	24th Sept.	26th Aug.	26th Aug.	26th Aug.	30th Sept.
Concern.	Barrah.			Belsund.		Benipore.	Motihari.			Pundoul.
Description.	Gondrah (Zerat)	Gondrah (Dehat)	Marri-pore.	Belsund.	Kutour village.	Benipore.	Bhelwa (medium).	Bhelwa (heavy).	Motihari.	Pundoul.
In 100 parts of dry soil.										
*Organic matter and combined water.	3·75	3·35	1·17	3·20	2·24	3·75	2·35	2·55	2·10	2·55
Sand and insoluble silicates	48·50	53·25	56·53	87·90	88·34	88·63	85·50	82·10	50·25	88·85
Phosphoric acid	·09	·12	·11	·10	·08	·17	·10	·11	·09	·12
Sulphuric acid	·02	·03	·02	—	—	—	·02	—	·01	·02
Carbonic acid, &c.	17·71	16·16	14·31	·70	1·09	1·21	·90	2·73	19·47	2·81
Oxide of iron	2·95	2·30	5·60	2·40	6·82	4·94	4·30	4·50	2·14	1·90
Alumina	2·50	1·45		2·95			4·55	6·25	2·03	2·85
Lime	22·50	20·80	20·85	1·05	·44	·43	1·70	·78	21·86	·40
Magnesia	1·65	2·22	·95	1·30	·54	·55	·22	·50	1·60	·16
Potash	·33	·32	·46	·40	·45	·32	·36	·48	·45	·34
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	·095	·075	·039	·080	·085	·189	·095	·090	·115	·065
Equal to ammonia	·115	·091	·047	·097	·103	·230	·115	·109	·139	·079
Average quality of indigo produced. Percentage of indigotin	65·68		59·65	48·66	—	58·30	62·80		64·85	56·10

TABLE VIIA.—COMPOSITION OF SOILS.

Date received (1898).	30th September.						16th December.			
Concern.	TURCOULEAH.						SEERAHA.			
							Seeraha.		Pareywah.	
Description.	Olaha.	Khoyrwa.	Tezpoor-wah.	Turcou-leah.	Chila-ram.	Ghyree.	Light Sandy.	Heavy Clay.	Light Sandy.	Heavy Clay.
In 100 parts of dry soil.										
*Organic matter and combined water	1·24	1·05	1·55	1·02	1·05	1·55	1·40	2·70	1·85	2·00
Sand and insoluble silicates	53·44	50·50	56·60	56·20	53·25	52·30	53·85	79·45	89·40	87·50
Phosphoric acid	·16	·18	·15	·14	·15	·18	·17	·15	·16	·13
Sulphuric acid	—	·05	·02	·03	·04	·04	·05	·04	·02	·04
Carbonic acid, &c.	18·44	17·81	15·48	16·22	19·17	16·67	17·37	2·78	2·56	1·06
Oxide of iron ... ... }	3·15	3·41	3·20	3·05	2·45	3·65	2·25	3·75	2·75	3·90
Alumina ... ... }		2·50	5·25	2·30	1·40	2·70	3·75	6·60	2·02	4·20
Lime	22·40	22·85	17·05	19·10	21·05	22·40	20·60	3·50	·45	·42
Magnesia	·85	1·20	·25	1.60	1·04	·15	·22	·45	·55	·45
Potash	·32	·45	·45	·34	·40	·36	·34	·58	·24	·30
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
*Containing Nitrogen	·048	·055	·050	·065	·048	·075	·065	·050	·040	·055
Equal to ammonia	·058	·066	·060	·078	·058	·091	·078	·060	·048	·066
Average quality of indigo produced. Percentage of indigotin	61·40	53·75	61·10	59·20	61·10	64·10	56·23		56·25	

TABLE VIII.—COMPOSITION OF LEAVES OF INDIGOFERA TINCTORIA (AIR DRIED).

Date received (1898).	16th Aug.	25th Aug.	25th Aug.	1st Sept.	26th Aug.	26th Aug.	26th Aug,	1st Sept.	2nd Oct.
Factory.	Doud-pore.	Gondrah (Zerat)	Gondrah (Dehat)	Marri-pore.	Bhelwa (medium).	Bhelwa (heavy).	Motihari.	Belsund (Kootour village).	Chitt-warrah.
Water	12·20	8·20	10·40	9·50	11·80	11·95	10·35	9·25	13·50
*Nitrogenous matter	31·90	31·80	24·81	34·68	30·82	29·75	27·60	23·75	28.35
Oil, &c., soluble in ether...	4·60	4·85	3·80	4·05	3·40	3·10	4·15	3.15	3·50
Woody fibre	7·45	10·85	13·25	10·62	12·30	11·82	12·20	9·60	8·72
Carbo-hydrates, &c.	34·45	34·10	36·24	27·05	28·38	29·38	34·50	39·85	37·53
†Mineral matter (ash)	9·40	10·20	11·50	14·10	13·30	14·00	11·20	14·40	8·40
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Matter soluble in water—									
Organic	30·10	23·25	28·35	24·35	20·60	19·65	26·95	26·90	25·25
Mineral	7·10	6·30	7·40	9·60	6·80	8·55	7·65	9·00	5·50
*Containing nitrogen...	5·04	5·02	3·92	5·48	4·87	4·70	4·36	3·75	4·48
†Constituents of Ash—									
Silica	·188	·418	·540	·721	1·165	·233	·465	·812	·240
Phosphoric acid	·950	·867	·897	·772	1·240	·970	·696	1·062	·922
Sulphuric acid	·341	·342	·322	·217	·278	·292	·261	·227	·146
Carbonic acid, &c.	1·522	—	—	4·496	2·654	4·459	2·647	3·618	1·743
Chlorine...	·050	·066	·069	·050	·028	·038	·043	·062	·050
Oxide of iron and alumina	·051	·055	·061	·106	·110	·063	·064	·144	·065
Manganese oxide	—	—	—	·047	·055	·030	·028	·038	·044
Lime	1·880	2·703	2·875	3·935	4·410	5·335	3·420	5·250	2·080
Magnesia	1·974	1·185	1·725	1·233	1·365	1·125	1·662	1·375	·730
Potash	2·444	2·601	2·472	2·523	1·995	1·455	1·914	1·812	2·380

TABLE IX.—COMPOSITION OF THE ASH OF VARIOUS SAMPLES OF THE LEAVES OF INDIGOFERA TINCTORIA.

Factory.	Doudpore.	Gondrah (Zerat).	Gondrah (Dehat).	Marripore.	Bhelwa (medium).	Bhelwa (heavy).	Motihari.	Belsund (Kootour village).	Chitt-warrah.
In 100 parts.									
Silica	2·02	4·10	4·60	5·12	8·75	1·66	4·15	5·63	2·86
Phosphoric acid...	10·10	8·50	7·80	5·50	9·32	6·92	6·22	7.37	10·98
Sulphuric acid	3·62	3·35	2·80	1·53	2·10	2·08	2·33	1·60	1·75
Carbonic acid, &c.	16·15	19·65	22·14	31·85	19·96	31·85	23·63	25·12	20·74
Chlorine	·52	·65	·60	·35	·21	·27	·38	·43	·60
Oxide of iron and alumina	·54	·53	·54	·75	·83	·45	·57	1·00	·77
Manganese oxide	—	—	—	·32	·42	·21	·25	·26	·52
Lime	20·02	26·20	25·02	27·90	33·15	38·12	30·53	36·47	24·76
Magnesia	21·03	11·52	15·00	8·74	10·26	8·05	14·85	9·54	8·69
Potash	26·00	25·50	21·50	17·94	15·00	10·39	17·09	12·58	28·33
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Indigo produced: Seers per 100 maunds green plant	8·2	12·25 (1897)		12·25 (1897)	10		10	—	—
Indigo produced: Percentage of Indigotin	66·25	65·68		59·65	62·80		64·85	—	—

Unfortunately I have not had the soils corresponding to two of these samples of plant, and in another case I have no figures showing the practical results obtained in the factory. It will at once be noticed that there is a striking difference in the composition of these samples of plant, not only in the percentage of nitrogen present, but in the percentage of mineral matter, and furthermore in the proportionate amount of the various constituents of the mineral matter. The plant from Doudpore is remarkable on account of the large percentage of magnesia present. The great differences exhibited in these analyses show that it is quite possible by careful cultivation to increase the amount of certain constituents, and no doubt the colour-forming body will be no exception.

II.—Manufacture of Indigo.

Manufacture viewed from three aspects.

For the study of improving the methods of manufacturing indigo as distinguished from the cultivation of the plant, I have viewed the question from three principal aspects. (1st) Observations made at various indigo factories in combination with communications regarding the past experiences of planters; (2nd) Experiments made with indigo plant in the chemical laboratory and in experimental vats; (3rd) Analyses of indigo made at various factories and comparison of the results with analyses of soils and water, and with the manufacturing returns of planters.

It will perhaps be best to discuss the question in the natural order of manufacture, from the cutting of the plant to the drying of the indigo cakes.

Cutting the plant and carting to factory.

Cutting and Carting.—The only remarks I have to make here are that, in many cases, I believe the plant is considerably injured by being exposed to the sun for a long time while on the way to the factory. In my opinion the steeping should be commenced with as little delay as possible after cutting. At one factory I saw plant which had been brought a distance of nine or ten miles; it was much withered. In such cases it would be much better to have two small factories in place of one large one. The best time for cutting the plant is generally considered to be just before it flowers, but the amount of colouring principle in the leaves at different stages of its growth has not been determined. As the plant very often grows faster than the factory can cope with it, the leaves cannot contain their

Maximum amount of colouring principle.

maximum amount of colour during the whole manufacturing season. This variation no doubt accounts in a great measure for the different results obtained during the season, and I shall endeavour to find some means of estimating approximately the amount of colouring principle obtainable from the growing plant.

Plant should be kept clean.

The plant should be kept as free as possible from earth. It is a waste of time purifying water, if the plant to be steeped contains a lot of earthy matter.

Loading the steeping vats.

Loading the Vats.—Much difference of opinion prevails among planters regarding the loading or packing of the vats. Vats are frequently much more heavily loaded on some days than others, and yet in certain cases the manufacturing returns are based upon the amount of indigo obtained per vat. I need scarcely say that to be of any value the returns should be based on the weight of plant steeped—say 100 maunds—and even then for purposes of investigation much depends upon the relative amount of leaves and stems constituting the plant. From manufacturing returns submitted to me, the amount of plant put into the vats appears to vary (omitting exceptional cases) from 140 to 180 maunds per 1000 cubic feet. In cases where comparative tests have been made better results have generally been obtained by light loading, and in my opinion this should be adopted.

Weight of plant per 1000 cubic feet vat capacity.

Steeping and extraction of the colour-giving principle.

Steeping.—This is perhaps the most important of all the processes of indigo manufacture. I believe it is in the extraction of the colouring principle that there is the greatest room for improvement. Whether in the future it will be best to continue the present method of extraction by fermentation on more systematic lines, or to extract the principle by some other means, I am not yet in a position to give an opinion, but I hope to arrive at some decision during the coming season. Notwithstanding the great amount of time that has been devoted to the subject, it is not definitely known in what state of chemical combination the colour principle exists in the leaf of the plant, nor the precise changes which take place during its conversion into indigo blue. It was formerly considered that indigo blue existed ready formed in the plant, and at a later period that it was present in the form of reduced indigo or indigo white. Many years ago Dr. Schunck, in his classical researches on the "Formation of Indigo Blue," proved both these views to be incorrect. He found the leaves of certain indigo-yielding plants

Views regarding the constitution of the colour-giving principle.

—the *Isatis tinctoria* and the *Polygonum tinctorium*—to contain a peculiar compound which he named *Indican.* Indican, which belongs to the class of bodies termed glucosides, is capable of being split up into indigo-blue and a kind of sugar. It has since been shown that this change does not take place directly, and that indican itself does not contain the molecule of indigo-blue. It is highly probable that the colouring matter exists in the same form in the leaves of the *Indigofera tinctoria* as in other indigo-yielding plants, but, as already stated, this has not been definitely proved. The little time that I have been able to devote to this question confirms on the whole the researches of Dr. Schunck, but I have observed certain differences which call for further investigation. A theory of the steeping process which appears to obtain generally is that by fermentation the glucoside, indican, is decomposed into indigo-blue and a peculiar kind of sugar, and that the indigo-blue is then by the action of further fermentation reduced to indigo-white, which remains in solution until it is afterwards precipitated by oxidation in the beating vat. This simple view of the process, however, is not borne out by facts. If the liquid running from the steeping vats contained indigo-white in solution it would be oxidised to indigo-blue in very much less time than is the case. Schunck and Römer have shown that when indican is decomposed by hydrochloric acid in the absence of oxidising agents a substance is produced which cannot be converted into indigotin. From the researches of these chemists Marchlewski and Radcliffe (*Jour. Soc. Chem., Ind.*, May, 1898) have propounded the theory that indican was a compound of glucose and indoxyl. Dr. Ranking, in a paper read before the Asiatic Society of Bengal in 1896, also states that the liquid after steeping probably contains indoxyl, and not indigo-white, as had been formerly considered to be the case. My own observations and experiments support this view. Indoxyl is a compound capable, like indigo-white, of being oxidised into indigo-blue, but for this change to take place it requires double the amount of oxygen needed for indigo-white.

Commonly accepted theory of steeping process probably incorrect.

Indoxyl probably formed and not indigo-white.

Fermentation by micro-organisms.

Much difference of opinion prevails as to whether fermentation is necessary for the production of indigo-blue, or whether the fermentation (which certainly does take place) is merely a consequence of the steeping process. It is possible to produce indigo-blue from the plant under such conditions that bacteria could not exist, and this would tend to show that fermentation was not a necessity. On the other hand, Alvarez professes to have discovered the micro-organism which produces the indigo fermentation. He cultivated the microbe (named the *Bacillus indigogenus*), and found that it induced indigo fermentation in a sterilised extract of the leaves which remained unaltered when freely exposed to the air without inoculation. Van Lookeren, Bandreat, and others attribute the formation of indigo to a

Diastatic fermentation.

"diastatic" fermentation, and not to the growth of a micro-organism. From my own observations I am inclined to think this is the correct view. This kind of fermentation is brought about by soluble fermerts or *enzymes*, which are highly complex organic bodies of an albuminoid character. A very small quantity is capable of bringing about chemical changes throughout a great mass of matter. One of the most common of this class of ferments is diastase, which exists in malt. It has the property of transforming starch into dextrin and glucose.

The liquid running from the steeping vat contains innumerable micro-organisms of a form similar to those described by Alvarez, but for the present my opinion is that they are not necessary for the production of indigo. For the coming season I have planned

Most suitable conditions of steeping.

a number of experiments to determine the most suitable conditions of steeping the plant. The object, in my opinion, should be to extract the colouring principles as rapidly as possible and not to wait specially for the development of any species of fermentation. As pointed out by Bridges-Lee, the leaves of the plant are covered with an immense number of small hairs, which are no doubt the chief cause of the leaves possessing the property of

Water repelling power of the leaf.

repelling water to such a high degree. This is also due to the vitality of the plant. The indigo leaf may be immersed in cold water for a considerable length of time without becoming wet. When the water comes into intimate contact with the leaf the colouring principle is very readily extracted. It is very soluble in water. The warmer the water the shorter is the time required for bringing the leaf and water into intimate contact. According to Schrottky leaf containing an abundance of starch and gum is of the best quality for producing indigo

Butyric fermentation.

on account of a vigorous *butyric* fermentation being set up and maintained. He has further recommended the addition of starchy matters in order to encourage and accelerate this fermentation. He states in the pamphlet previously referred to that in the steeping process the principal gas set free is hydrogen accompanied by carbonic acid gas and a little ammonia. Also, that during the fermentation the temperature of the water in the vat rises four to six degrees, but after hydrogen ceases to be evolved in large quantities, the temperature falls five or six degrees in the course of half-an-hour. When a fall of temperature takes place, or when hydrogen ceases to be evolved, he considers the proper time for drawing off the liquor. My own observations and experiments are not in accordance with these statements. I found carbonic acid gas to be given off during steeping in far greater quantities than hydrogen. Dr. Ranking also found a much greater proportion of carbonic acid gas given off than hydrogen. As far as my experience goes, I consider that the operation of steeping is complete when hydrogen gas is being rapidly evolved, and that nothing is gained by prolonging the process. Regarding the temperature of the vats during steeping, I made numerous observations at different factories and found no appreciable rise during any time of the process. Some indicator by means of which it could be ascertained when plant was sufficiently steeped is a desideratum. Perhaps the simpliest way will be to have a scale of hours of steeping according to the temperature of the water. This scale must of course be worked out by direct experiment, and I hope to take this in hand at once on my return to India.

Gases evolved during steeping process.

Temperature of steeping vats.

Indication when plant is sufficiently steeped.

Second Steeping.—After the solution has run off, the plant is, of course, saturated with the same liquid, and even if all the colouring principle is extracted from the leaf it would appear that a second steeping or at least a washing would be advantageous. It has been found in practice, however, that a second steeping is unprofitable. Certain chemical and bacteriological changes take place much more rapidly on wet matter offering a great surface than when the same material is either dry or completely immersed in water. Whilst the liquid is draining off from the plant, it would seem that the colour-giving principle which is left in solution on the leaves and twigs is rapidly decomposed and destroyed. A portion forms indigo blue, but this is left on the plant in an insoluble state, and is, therefore, not extracted by a second steeping. After the water has run off the temperature of the plant rises rapidly.

Second steeping of little or no value.

Water used in Steeping.—The amount of water required to produce one part of indigo is enormous, and, therefore, the quality of the water used in steeping the plant is a matter of great

Quality of water used in indigo manufacture.

importance. It is generally recognised by planters that the kind of water used affects both the quality and quantity of the indigo produced. From my past experience with water required for various industrial purposes, I looked forward to this question with much hope of bringing about at once great improvements in the manufacture of indigo, but I was disappointed. It was one of the first problems that I took in hand at the Mozufferpore laboratory, but I did not find, as I had fondly expected, the master-key to the situation. I tested a great many samples of water, but they were sent in so rapidly that with the apparatus at command it was only possible to make a few determinations in each sample. It would have been better if more detailed analyses had been made of a few typical waters. Some waters were found to be much harder than others, and it has generally been understood that hard limy water was not suitable for indigo manufacture. I have come to the conclusion, however, that the mineral constituents are not of very great importance, but that much depends upon the presence or absence of certain forms of organic life. Softening the water has been found to be beneficial, but in my opinion, the good results obtained in such cases are not due to the mere removal of lime from solution, but to the fact that the precipitate carries down with it micro-organisms which otherwise would act injuriously. I fully believe that many waters, especially those which are of a stagnant character would be greatly improved for indigo manufacture by their undergoing a treatment of precipitation and filtration, or precipitation and mere subsidence. In this respect, my conclusions agree with those of E. C. Schrottky. When it is considered that a water containing twenty grains of carbonate of lime per gallon is a very hard water, and that the liquid in which indigo has been steeped, frequently contains as much as 200 grains per gallon, it cannot be expected that a few grains more or less at the commencement will have any material effect upon the steeping process.

Testing waters.

Waters best which are free from organic matters.

Treatment of waters.

Tables X. and XA. show the amount of total solids, alkalinity, hardness and sodium chloride, in a number of samples of water. Several other tests for nitrates, nitrites, sulphates, organic matter, &c., were also made and noted. I am afraid these results will not prove of much practical value; it will he necessary to study the characters of two or three typical waters in much greater detail, and on account of the rapid changes which take place in samples of water during the hot weather season, some of the

More detailed analyses of typical waters required.

TABLE X.—SHOWING TOTAL SOLID MATTER, ALKALINITY, HARDNESS, &c., OF WATERS.

Date Received	Concern.	Description.	Grains per Gallon.				Indigo Produced.
			Total Solids.	Alkalinity (as $CaCO_3$)	Hardness.	Sodium Chloride.	Percentage of Indigotin.
1898.							
27 Aug.	Barrah	Gondrah	12·32	8·70	6·5	·55	65·67
1 Sep.	,,	Jugowleah	11·20	7·84	6·1	·25	60·91
4 ,,	,,	Barrah River	14·00	10·90	8·5	·35	—
,, ,,	,,	,, Tank	7·50	7·00	5·7	·50	—
28 July	Belsund	Lake	14·77	6·09	5·0	·65	} 48·00
,, ,,	,,	River	14·98	8·60	6·8	·65	
7 Aug.	,,	Bogwanpore	14·70	9·38	6·6	·45	—
28 ,,	,,	Bellailie	19·81	10·76	9·5	·30	55·75
29 July	Bhatowlia	River	9·24	5·02	5·1	·55	64·65
27 ,,	Dholi	Birowli River	13·58	6·30	5·7	·45	57·15
,, ,,	,,	Subnaka Rain	22·05	7·80	7·7	·45	59·50
31 ,,	Dooriah	Dooriah River	21·40	7·90	7·0	·35	65·95
,, ,,	,,	Kurramwaree Tank	—	7·70	7·3	·40	68·55
,, ,,	,,	Shapore Tank	20·30	7·20	7·2	·45	66·25
,, ,,	,,	Dooriah Tank	17·22	8·12	7·4	·40	—
,, ,,	,,	,, Big Gunduck	17·50	5·88	6·1	·45	—
25 ,,	Doudpore	Mooshery	14·98	5·60	5·5	·55	64·55
31 ,,	,,	Arrajepore	14·14	8·00	7·9	·40	66·45
12 Aug.	Gopalpore	Gopalpore	15·85	8·26	6·8	·30	62·30
22 ,,	Hurdeah	Hurdeah	11·80	3·25	2·7	·65	58·30
10 ,,	Ilmasnugger	Ilmasnugger	11·76	7·14	6·7	·45	—
,, ,,	,,	Messina	8·73	6·30	4·0	·25	—
29 July	Kanti	Manufacturing	14·07	6·58	6·3	·45	59·60
31 ,,	Kootopur	Tank	22·40	6·16	5·7	·75	57·35
10 Aug.	Kurhurie	Byr River	8·82	4·90	5·5	·30	65·60
10 Sep.	Mooktapore	Mooktapore	—	8·82	7·3	·40	68·15
,, ,,	,,	Chukmehri	—	9·66	7·9	·60	66·85
26 Aug.	Motihari	Motihari	11·20	6·72	6·0	·75	64·85
,, ,,	,,	Bhelwa	8·70	6·30	6·0	·45	62·42
28 ,,	Motipore	Chucklouron A	29·82	8·82	6·5	·45	—
,, ,,	,,	,, B	12·81	7·70	6·2	·40	—
28 July	Padamkair	Lake	9·24	3·50	3·5	·30	—
,, ,,	,,	Tank	6·26	3·01	3·0	·35	—
,, ,,	,,	Well	20·02	9·80	7·5	·45	—
30 Aug.	Peeprah	Lake	10·50	6·10	5·2	·45	} 63·25
,, ,,	,,	Tank	10·08	6·50	5·1	·30	
3 Sep.	Piperundie	Tank	4·00	3·92	2·6	·75	62·90
,, ,,	,,	Well	31·08	21·04	—	1·00	—
1 Sep.	Pursa	Pursa old Tank	28·35	20·02	13·8	2·00	63·15
,, ,,	,,	,, new ,,	15·50	8·82	6·0	·70	—
,, ,,	,,	Sickhya Tank	11·90	6·50	4·8	·50	61·25
,, ,,	,,	,, River	16·80	11·58	9·6	·35	—
21 July	Rajkund	Rainwater fr. Tank	58·80	4·10	3·0	·65	55·46
,, ,,	,,	Luckindai River	30·45	5·04	4·5	·75	60·35
29 Aug.	Rajpore	Rajpore	11·62	8.40	5·5	·22	60·15
,, ,,	,,	Hossain Tank	11·70	9·00	7·0	·44	64·50
,, ,,	,,	,, Dhouri	12·60	9·50	6·0	·40	—

TABLE XA.—SHOWING TOTAL SOLID MATTER, ALKALINITY, HARDNESS, &c., OF WATERS.

Date Received.	Concern.	Description.	Grains per Gallon.				Indigo Produced.
			Total Solids.	Alkalinity (as $CaCO_3$)	Hardness.	Sodium Chloride.	Percentage of Indigotin.
29 Aug.	Rajpore ...	Pucrie	—	5·88	14·1	·35	59·40
,, ,,	,, ...	Jumnapore	7·15	6·16	6·2	·25	55·75
4 July	Seeraha	Seeraha Tank ...	26·46	19·74	—	·66	} 56·30
,, ,,	,, ...	,, Lake ...	12·60	6·35	5·6	·33	
,, ,,	,, ...	Pereywah	14·84	9·38	7·5	·67	57·80
30 ,,	Singhia	Singhia Gunduck...	17·22	5·88	4·6	·45	68·45
,, ,,	,, ...	Chuckdowlit Baya..	9·38	5·32	4·7	·35	65·60
,, ,,	,, ...	Nawadi...	12·74	7·42	6·8	·35	65·25
,, ,,	,, ...	Powra	—	6·90	7·0	·30	67·50
,, ,,	Sitalpore ...	Manufacturing ...	17·22	10·08	8·8	·30	—
20 ,,	Tatareah ...	Tatareah Tank ...	16·80	6·72	6·7	·67	} 67·20
,, ,,	,, ...	,, Lake ...	15·40	7·28	4·8	·50	
,, ,,	,, ...	Bala old Tank ...	15·40	7·00	5·0	·50	—
,, ,,	,, ...	,, new ,, ...	15·24	5·80	5·4	·48	—
,, ,,	,, ...	Tatareah new Tank	17·20	6·70	6·3	·55	—
20 Aug.	Turcouleah ...	Turcouleah	13·30	6·44	6·4	·35	59·20
,, ,,	,, ...	Olaha	13·86	7·10	5·8	·25	61·40
,, ,,	,, ...	Ghyree	14·42	9·00	6·0	·75	64·10
,, ,,	,, ...	Khoyrwa	13·86	7·00	5·8	·35	53·75
,, ,,	,, ...	Muckhwa	15·80	6·20	6·0	·30	62·86
,, ,,	,, ...	Jallaha	15·12	9·00	7·0	·40	61·33
,, ,,	,, ...	Burhurwa	9·00	8·50	6·6	·25	61·15
,, ,,	,, ...	Suckhwa	11·50	7·70	5·5	·50	64·46
,, ,,	,, ...	Chileram	12·70	10·20	6·6	·50	61·10
,, ,,	,, ...	Doodhahi	15·10	9·80	6·8	·50	63·08
,, ,,	,, ...	Teypoorwah	9·80	7·00	5·8	·25	61·10

tests must be made on the spot. I was rather surprised to find the bulk of the waters either free from nitrates, or containing but faint traces. The only samples containing an appreciable amount of nitrates were those of Kanti, Shapore, and Dooriah tank, and in these cases there was considerably less than a grain per gallon. Two waters call for special notice, on account of the large amount of solid matter present. These are the samples from Rajkund. The sample marked "Rain water from tank" contains 58·8 grains per gallon, but the main portion (44·8 grains) consists of clay in a very finely-divided state, and which remains in suspension for a great length of time. The indigo made with the use of this water contains on an average 55·38 per cent. indigotin, and 11·84 per cent. mineral matter, chiefly clay. The

Mineral matter (clay, &c.) in suspension.

water on being filtered is remarkably pure, and if this were done a much finer quality of indigo would be produced. "Luckindai" river water also contains much suspended matter, though less than the water from tank. The percentage of mineral matter in the indigo made with it is only 5·92. Although "River" water gives a better *quality* of indigo, it has always been found that "Rain water from tank" produced a greater yield of dye.

Taking all the samples examined into consideration, it is impossible at present to draw any definite conclusions regarding the effect of the various constituents upon the quality and quantity of indigo produced. As already mentioned, it is necessary to go much deeper into the question, particularly as regards the organic matter present in solution and suspension. From a practical point of view, I believe all waters could be greatly improved by a process of precipitation and filtration.

Properties of solution obtained by steeping the plant.

Liquid obtained by Steeping and its Treatment (beating).—The liquid running from the steeping vat varies in colour from a bright orange to an olive green, and possesses a peculiar fluorescence. It contains a number of substances—organic and inorganic—in solution, among which the most important, the indigo-forming principle, exists in very small proportion. An extract of indigo leaves has been variously stated to possess an acid, an alkaline, and a neutral reaction. But I have never seen any statement made regarding the indicator used for determining this condition. Many substances which exhibit an acid reaction to some indicators are alkaline to others. This is the case with an extract of indigo leaves. I found a fresh decoction of the plant to be neutral to both red and blue litmus paper. It was decidedly alkaline to methyl orange and acid to phenolphthalein. The liquid contains a large amount of lime, magnesia, and potash; chiefly in combination with carbonic and organic acids. I have analysed twenty samples of "liquor" and found the solution to contain on an average 0·55 per cent. of dry solid matter. [The maximum was 0·79 per cent., and the minimum 0·35 per cent.]. This amount corresponds to 55lb. per 1000 gallons, or, in round numbers, to 170 seers per 1000 cubic feet. Nearly one-half of the total solids consists of mineral matter; bi-carbonates of lime, magnesia, and potash predominating.

Solid matter present in solution.

Difference between leaves and stems.

The bulk of this matter, and practically the whole of the colouring matter, is derived from the leaves. Even the fine stems yield but traces of colour. In order to show the relative ɔunt of matter extracted from leaves and stems, 100grms. ɜach were separately steeped with ten times their weight of er in the usual manner, and the following results were ained. The plant in this case (Marripore) contained 38 per t. of leaf. The results are also calculated for the whole nt.

[ABLE XI.—SHOWING RESULTS OBTAINED ON STEEPING LEAVES AND STEMS SEPARATELY.

	Leaves.		Stems.		Whole Plant.	
	In Liquid per cent.	Calculated on Leaves per cent.	In Liquid per cent.	Calculated on Stems per cent.	In Liquid per cent.	Calculated on Whole Plant per cent.
otal Solids ...	1·014	10·14	·185	1·85	·500	5·00
ineral Matter...	·263	2·63	·043	·43	·126	1·26
kalinity expressed as carbonate of lime	·260	2·60	·080	·80	·148	1·48
digotin	·052	·52	traces	—	·020	·200
digotin expressed as a 60% indigo...	·086	·86	—	—	·033	·333

The indigotin in this instance only equals one twenty-fifth t of the total matter extracted from the plant, but the amount responds to 13⅓ seers of 60 per cent. indigo per 100 unds of plant. In several other experiments I found the ves to yield from ·30 to ·60 per cent. indigotin. From the nufacturing returns of thirty-one factories submitted to me, I ve found the average amount of indigo produced per 100 unds of plant in 1898 to be 9·7 seers. The highest recorded s 12·8 seers, and the lowest 6 seers per 100 maunds.

Under normal conditions from two to three hours are uired to complete the operation of beating; although in ne cases, the length of time may be reduced to one or one and alf hours. I have found even on a small scale, that the ɜration still usually took about two hours to complete. ɔm this one might reasonably infer that the solution did not ntain indigo-white, since indigo-white is rapidly oxidised to ligo-blue by the action of air. Moreover, during the beating ɔcess the froth has not the same appearance as that produced ring the oxidation of a solution of indigo-white. On account of some vats in a range being ready sooner than others, it happens in many cases that the liquid is allowed to stand several hours before it is beaten. In order to avoid this delay, in some factories the whole of the steeping vats in one range are opened at once, but as it is not practicable to fill all the vats at one and the same time, some plant is no doubt under-steeped, and some over-steeped. In my opinion it would be preferable to sub-divide the beating vat into a number of smaller ones, and beat each lot of liquid at once when ready. This would not entail much alteration in plant and machinery.

Small beati vats.

Addition of alkalies.

If an alkali such as lime, soda, or ammonia be added to the liquid from the steeping vat, the carbonic acid, which is present in great quantities, is neutralised, and calcium and magnesium carbonates are precipitated. At the same time, the character of the indigo-yielding body evidently undergoes a change, as it may now be readily oxidised to indigo-blue; in fact, the solution has all the appearances of a weak indigo-dyeing vat, containing indigo-white or reduced indigo. The addition of alkalies has formed the subject of several patents. The want of success, however, has been due to the fact that the indigo thus obtained was necessarily contaminated with the precipitated lime and magnesium carbonates. In order to obviate this difficulty, Coventry introduced his system of using an intermediate vat, which retains the precipitated matter. If the liquid to be treated is perfectly clear, the precipitate obtained on the addition of an alkali consists almost entirely of mineral matter, but if it contains matter in suspension a considerable amount of organic matter is also removed. The indigo obtainable by Coventry's process is of very high quality, and it usually contains a very much greater proportion of indigo-red than indigo made in the ordinary way. The formation of indigo-red always occurs when an alkali is added in slight excess to the liquid from the steeping vat. The proportion of indigo-red formed appears to be dependent upon the amount of alkali added in excess, and the length of time occurring between this addition and beating. The production of indigo-red under these conditions is very strong evidence in support of my previous statements: that the liquid obtained on steeping indigo plant does not consist of a solution of indigo-white. Indigo-white is not changed into indirubin or indigo-red by the action of alkalies.

Calcium an magnesiun carbonates precipitate

Coventry's process.

Formation indirubin.

In the ordinary beating process, when the operation is nearing completion the froth breaks readily, and it appears whiter than it did previously. As an indication of complete oxidation or conversion into indigo-blue, I cannot recommend at present anything better than that which is already in vogue with many planters. A piece of filter paper or white blotting paper is saturated with the liquid and subjected to the fumes of strong ammonia. If the operation of beating is not complete a faint blue colouration is produced. The injurious effects obtained by prolonged beating appear to be due entirely to mechanical action. There is no evidence to show that indigo once formed is actually destroyed, but the fecula does not readily settle and a greater proportion is lost in running off the seet water.

ndication of ompletion f beating rocess.

mount of ndigotin resent in eet water.

Seet Water.—The indigo fecula after beating sometimes settles much more readily than at other times. The subsidence may be retarded by over-steeping or over-beating, or by allowing the liquid to stand a long time before beating. In all cases, however, the water which runs to waste contains some indigo, more or less, in suspension. In six samples of seet water, I found the following percentage of indigotin:—

No. 1	= ·0023	mean = ·0024 per cent.
,, 2	= ·0020	
,, 3	= ·0015	
,, 4	= ·0024	
,, 5	= ·0039	
,, 6	= ·0023	

The mean result (·0024 per cent.) is equivalent to a loss of about 8—10 per cent. of indigo. In my opinion, a great portion of this indigo might be recovered either by running the seet water into a tank to allow the particles to subside (by aid of a preciptant if necessary), or by passing the liquid through a filter press. The seet water contains in solution a considerable amount of nitrogenous matters, as well as potash salts, and should be utilised as much as possible as a fertiliser for land in the neighbourhood of the factories.

eet water of alue or a ertiliser.

ther rocesses of xtracting e colour- iving rinciple than y steeping.

Other Processes of Extraction.—Before proceeding to discuss the subsequent processes of manufacture it will perhaps be well to say a few words at this stage about methods of extraction other than those commonly in use. There are two points to which I wish to draw attention, and although I am aware the methods have been previously tried and discarded, it is quite possible that one or both with certain modifications may yet prove of value.

Extraction with Hot Water.—I believe experiments have been made in several factories with hot water, and I should be glad to have details of results which have been obtained. On a small scale in the laboratory I have found extraction by hot water (at 150 to 160°F.) to work well, but it is necessary to beat off immediately, otherwise a great loss of indigo results. During the coming season I intend making experiments on a somewhat larger scale, and as already stated should be glad to know what have been the past experiences of others in this direction, particularly as regards the objectionable features of the process. **Hot water.**

Extraction of Leaves only.—It is generally understood that the stems of indigo plants yield little or no colouring matter. For practical purposes the colouring matter in stem may be regarded as *nil.* I have already drawn attention to the great variation in the proportion of leaves and stems in different crops. On account of these variations it is difficult to draw any conclusions as to whether different results in quality or yield of indigo are due to the plant itself, or to the process of manufacture. If the leaves only were taken to the factory, I fully believe a great many variations in produce which have puzzled planters so long would disappear. Moreover, the stems yield to water during the steeping process a number of gummy substances which tend to deteriorate the quality of the indigo produced. I have also observed that the stems furnish material which brings about a much more rapid development of micro-organisms of an injurious character than the matter furnished by the leaves. No doubt there are many practical difficulties in the way of taking leaves only to the factory, but I do not think they are insuperable. Many years ago a method patented by Olpherts was introduced, and I believe further experiments on similar lines to be well worthy of consideration. From a manufacturing point of view the advantages would be unquestionable. The chief drawback no doubt is the cost and trouble of gathering the leaves, but this question I must leave for planters to discuss. There would be less cartage to and from the factories, and the stems could finally be ploughed into the land with advantage. **Advantage of extract leaves onl**

Boiling.—After the supernatant liquid seet water has run off, the precipitated indigo, or "mal," is pumped up into iron vessels to be boiled. There is a three-fold object in boiling the **Boiling or heating.**

"mal": 1st, it prevents putrefaction (a kind of fermentation), which would cause a loss of indigo; 2nd, it dissolves some of the brown matters which have precipitated with the indigo fecula, and thus produces a finer quality; 3rd, it causes the indigo particles to settle more readily, so that the useless liquid portion may be run away. Although the process is called "boiling," the liquid paste is not always boiled. It is heated (now usually by steam, but in some cases direct by fire, or by steam and direct fire combined) up to temperatures varying from 190° to 212°F. Some planters attach much importance to actually boiling the "mal," but in my opinion there is little, if anything, gained by heating beyond 210°F. As mentioned in my report of the 14th July last, I strongly recommend washing the "mal" in the boiler. That is, after once heating, allowing the "mal" to settle, running off the liquid, adding fresh water (preferably hot), and heating up a second time. A block of indigo taken from the press contains on an average about 70 per cent. of water. When no washing has taken place, the water will hold in solution at least as much soluble matter (probably more) as the original seet water—about 0·55 per cent. This corresponds to 1·3 per cent. of dry "seet" in the indigo cake. As a matter of fact there is considerably more than this amount of soluble matter present. I have found that boiling water removes from three to six per cent. of extraneous gummy matters from good Bengal indigo. If this were removed, or the greater portion of it, by washing in the boiler, the indigo would be considerably improved in quality; there would be much less mould formed in drying, and there would be less liability of "bukra" indigo being produced. If, instead of water only, dilute hydrochloric or sulphuric acid were used, the indigo would be still further purified. By boiling with hydrochloric acid from 15 to 20 per cent. of impurities may be removed from ordinary Bengal indigo.

ashing in e boiler.

rification acids.

essing and tting.

Pressing and Cutting.—These are entirely mechanical operations, which call for little comment. I would merely remark that the subsequent drying operation would be greatly facilitated if the cake were cut thinner. Instead of 3in. cubes I would suggest cakes of 3in. square by 1in. or 1½in. in thickness. Taking into consideration the present mode of selling indigo, I don't recommend that this change should be made at once, but merely throw it out as a suggestion.

Drying.—On first entering the drying-house of an indigo factory I was much struck with the thick growth of fungus to be seen on the cakes and the great amount of ammonia being evolved. I came to the conclusion that there must be a great loss of colouring matter taking place in this operation, and at once arranged a series of experiments to discover if such was the case. Much to my surprise, the results of these experiments have not confirmed the opinion I had formed. I had samples of paste (from the press) sent to me from six different factories, and afterwards samples of the same indigo at intervals of two to four weeks during the drying process, and submitted them to a careful analysis. The samples were not sent as regularly as I should have wished, but the results which are tabulated below show that little or no destruction of colouring matter took place. I intend, however, to make further tests during the coming season. **No evidenc loss of colo ing matte drying.**

TABLE XII.—Showing percentage of Indigotin in Samples of Indigo at Different Stages of Drying Process.

	Percentage of Indigotin on Dry Indigo.					
Name of Factory.	Tatareah.	Belsund.	Jugowleah.	Gondrah.	Marripore, Jugowleah.	Rajkund.
Paste from Press...	71·25	50·50	64·00	—	63·50	57·20
First Cake ...	71·60	51·12	64·40	69·60	63·00	58·00
Second " ...	71·80	51·40	64·50	70·20	63·90	57·50
Third " ...	—	51·00	65·40	69·80	63·85	—
Fourth " ...	—	—	65·00	70·00	63·20	—

The drying process is a long operation, and although I am aware if dried quickly the cakes are liable to crack, still I am of opinion that some better system might be adopted, and hope soon to put one or two ideas I have on the subject into practice. As already mentioned, the time would no doubt be shortened by cutting into thinner cakes. When the air is saturated with moisture no drying can take place in the best ventilated drying houses. **Better syst of drying desirable.**

I have often been asked to offer an explanation regarding the formation of "bukra" indigo. The formation, however, appears to be so erratic that it is difficult to find a satisfactory explanation. It is probably due to a species of fermentation whereby **Formation "bukra" indigo.**

gases are evolved which cause a rupture of the cake. The formation of "bukra" indigo does not seem to be accompanied by a reduction in quality. Of two samples of indigo received from Tatareah, one marked "Sound" and the other "Buckra" (presumably made on the same day), the bukra actually contained two per cent. more indigotin than the sound sample. No doubt the original paste was superior in the one case than the other, and further tests are required in order to ascertain if any deterioration in quality does take place.

apely kes, wder, and ste.

Under existing conditions regarding the sale of indigo, a sound, shapely cake is a matter of much importance, but from a practical dyeing point of view, the whole process of cutting into cakes and careful drying, so as to avoid breaking the same, is a waste of time and money. Almost all dyes are now sent out either in the form of powder or paste. Before indigo can be used for dyeing it must either be ground to powder for solution in sulphuric acid, or to a smooth paste for subsequent reduction in the vat. The great bulk of the indigo consumed in dyeing is used in the latter form. Now the paste or "mal" collected on the table ready for pressing is just in the condition as required for the dye vat. The particles of indigo are in an exceedingly fine state of division, a condition necessary for the successful working of the vat. On drying, the indigo becomes hard and more or less gritty, and it requires to be ground with water for many days before it is sufficiently fine to be used in dyeing. From a dyeing point of view, therefore, the best form to send out the product would be that as collected on the table. In this form, however, with the natural impurities still present, the mass is liable to undergo putrefaction, although *pure* indigotin does not change. A great deal of time and some expense would be saved if, instead of pressing, cutting, and slow drying as at present carried out, the paste was at once dried by mechanical means and ground to powder.

actical ficulties.

Having regard to the existing methods of selling indigo, I am aware there are many practical difficulties in the way of making such a great change. I merely draw attention to the matter in order to show what the dyer really requires, and how the expenses incurred in manufacture may possibly be reduced so that indigo may compete successfully with artificial dyes.

alyses of ligo.

I have analysed a number of samples of indigo from various factories in Behar, and the results are shown on Table XIII.

TABLE XIII.—Analyses of Indigo.

Date Received.	Concern.	Description or Mark.	Calculated on the Dry Samples. Ash. per cent.	Calculated on the Dry Samples. Indigotin and Indirubin. per cent.	Calculated on Samples containing 6% Water. Ash. per cent.	Calculated on Samples containing 6% Water. Indigotin, and Indirubin. per cent.	Indigo Produced. Seers per 100 Maunds Green Plant.
1898.							
27 Aug.	Barrah	Jugowleah, 1st cake	3·85	64·40	3·62	60·55	—
29 ,,	,, ...	Gondrah ,,	3·25	69·60	3·05	65·40	—
4 Sep.	,, ...	Jugowleah, 2nd ,,	4·00	64·50	3·76	60·65	--
,, ,,	,, ...	Marripore, 1st cake	3·50	63·00	3·29	59·20	—
10 ,,	,, ...	Gondrah, 2nd ,,	3·30	70·20	3·10	66·00	—
1 Oct.	,, ...	M & H / J M 2	3·90	63·90	3·66	60·05	—
,, ,,	,, ...	,, 3	3·40	63·85	3·20	59·95	—
,, ,,	,, ...	,, 4	3·36	63·20	3·10	59·40	—
,, ,,	,, ...	BG 3	3·14	69·80	2·95	65·50	—
,, ,,	,, ...	,, 4	3·40	70·00	3·20	65·80	--
,, ,,	,, ...	J 3	3·90	65·40	3·66	61·45	—
,, ,,	,, ...	,, 4	4·03	65·00	3·76	61·00	—
20 July	Belsund... ..	1897 No. 8... ...	14·70	54·00	13·81	50·75	—
,, ,,	,, ...	,, ,, 52... ...	10·40	54·60	9·77	51·30	—
,, ,,	,, ...	,, Average ...	11·86	53·95	11·09	50·65	—
31 ,,	,, ...	First cake	15·10	51·12	14·19	48·05	—
7 Aug.	,, ...	3 June 4th	20·60	43·10	19·36	40·50	—
,, ,,	,, ...	20 ,, 21st	14·58	58·75	13·63	55·15	—
28 ,,	,, ...	Second cake	15·25	51·40	14·33	48·31	—
,, ,,	,, ...	Bellailie 4	9·49	59·40	8·83	55·75	—
28 Sep.	,, ...	Third cake	15·20	51·00	14·28	47·95	—
30 ,,	,, ...	98 flood	5·25	55·40	4·88	52·05	—
24 ,,	Benipore ...	11	8·46	62·00	7·89	58·30	—
,, ,,	,, ...	42	3·90	65·20	3·66	61·25	—
2 ,,	Bhatowlia ...	Bhatowlia	1·90	68·85	1·78	64·65	—
,, ,,	,, ...	Mia Chupra	10·20	53·00	9·58	49·80	(11·3) average.
4 Aug.	Dholi	C McK ES B 26 ...	5·66	60·75	5·26	57·15	8·20
,, ,,	,, ...	,, SM 23 ...	6·10	63·30	5·73	59·50	8·75
5 Sep.	Dooriah ...	D 41	3·77	70·10	3·47	65·90	—
,, ,,	,, ...	K 47	4·80	72·95	4·51	68·55	—
,, ,,	,, ...	S 29	3·57	70·60	3·29	66·25	—
,, ,,	,, ...	46	4·86	71·90	4·51	67·55	—
30 Aug.	Doudpore ...	38 Ordinary	3·76	65·95	3·47	61·95	—
,, ,,	,, ...	41 P	2·60	66·20	2·44	62·20	—
6 Sep.	,, ...	45	2·75	65·30	2·58	61·40	—
,, ,,	,, ...	46	2·86	64·90	2·63	61·00	—
,, ,,	,, ...	47	2·88	64·00	2·63	60·15	—
29 ,,	,, ...	C & B / D 32	2·67	70·50	2·44	66·25	8·20
,, ,,	,, ...	M 34	3·40	68·75	3·19	64·55	9·72
,, ,,	,, ...	A 34	2·70	70·75	2·53	66·45	8·42
,, ,,	,, ..	C 21	4·30	70·35	4·04	66·10	8·60

TABLE XIII.—ANALYSES OF INDIGO—*continued.*

Date Received.	Concern.	Description or Mark.	Calculated on the Dry Samples. Ash. per cent.	Calculated on the Dry Samples. Indigotin, and Indirubin. per cent.	Calculated on Samples containing 6% Water. Ash. per cent.	Calculated on Samples containing 6% Water. Indigotin, and Indirubin. per cent.	Indigo Produced. Seers per 100 Maunds Green Plant.
1898.							
23 Aug.	Dulsing Serai	R O 9	3·99	75·78	3·76	71·25	—
,, ,,	,, ...	A K B 13	2·60	78·70	2·44	74·00	—
,, ,,	,, ...	R B 41	1·78	78·80	1·59	73·95	—
,, ,,	,, ...	P O H 51	3·55	77·00	3·33	72·30	—
,, ,,	,, ...	I M O G 57	2·27	83·65	2·06	78·60	—
,, ,,	,, ...	D H S M 69	1·45	82·05	1·31	77·15	—
19 Sep.	,, ...	L M O C 57 ...	3·40	90·80	3·19	85·35	—
,, ,,	,, ...	D H S M 91 ...	2·39	83·30	2·16	78·30	—
,, ,,	,, ...	99 Ordinary	7·73	54·65	7·23	51·30	4·05
,, ,,	,, ...	100 Patent	15·75	72·60	16·73	68·25	2·10
,, ,,	,, ...	101 ,, ...	2·09	86·50	1·97	81·30	2·77
,, ,,	,, ...	102 Ordinary ...	6·94	53·45	6·48	50·30	3·42
30 ,,	Gopalpore ...	McL &c. 45	4·67	66·30	4·32	62·30	—
22 Aug.	Hurdeah ...	51 16/8/98	5·05	62·00	4·70	58·30	—
29 Sep.	Kanti	64	2·57	60·15	2·35	56·50	11·38
,, ,,	,, ...	66	2·50	64·75	2·35	60·80	11·44
,, ,,	,, ...	68	2·18	65·50	1·97	61·55	10·00
31 July	Kootopur ...	Kootopur 6/14 ...	11·56	61·00	10·81	57·35	—
22 Aug.	Kurhurie ...	38	2·37	69·80	2·16	65·60	—
,, ,,	,, ...	Average of 4 samples	3·08	70·85	2·89	66·55	—
29 Sept.	Mooktapore ...	Chukmehri	4·89	71·15	4·51	66·85	11·88
,, ,,	,, ...	Mooktapore	3·33	72·55	3·10	68·15	10·47
4 ,,	Motihari ...	Bhelwa	4·10	66·80	3·85	62·80	10·00
,, ,,	,, ...	Motihari, 1st cake	1·85	69·00	1·74	64·85	10·00
27 ,,	,, ...	Bhelwa 53	4·65	66·25	4·32	62·05	—
15 Nov.	Peeprah... ...	... ...	3·38	67·35	3·10	63·25	—
16 ,,	Piperundie ...	... ...	4·50	66·95	4·23	62·90	—
30 Sept.	Pundoul ...	Gale P 6	7·00	60·00	6·58	56·40	6·14
,, ,,	,, ...	,, P 25	7·12	57·90	6·67	54·40	7·10
,, ,,	,, ...	,, P 35	8·63	61·20	8·08	57·50	6·50
,, ,,	,, ...	,, N 5	10·02	55·60	9·40	52·15	4·75
,, ,,	,, ...	,, N 23	6·96	62·40	6·48	58·55	5·74
,, ,,	,, ...	,, N 38	6·67	59·40	6·20	55·75	4·16
,, ,,	,, ...	,, L 6	8·99	60·75	8·36	57·05	4·36
,, ,,	,, ...	,, L 14	11·73	54·90	10·99	51·60	5·03
,, ,,	,, ...	,, L 30	7·19	63·10	6·67	59·30	8·60
1899.							
24 Jan.	Pursa	Sickhya	5·10	65·15	4·79	61·25	—
,, ,,	,, ...	Pursa	3·85	67·20	3·62	63·15	—
1898.							
31 July	Rajkund ...	First cake	13·45	58·00	12·64	54·50	—
17 Aug.	,, ...	30 River	6·35	64·20	5·92	60·35	10·63

TABLE XIII.—Analyses of Indigo—*continued.*

Date Received.	Concern.	Description or Mark.	Calculated on the Dry Samples. Ash. percent.	Indigotin and Indirubin. percent.	Calculated on Samples containing 6% Water. Ash. percent.	Indigotin and Indirubin. percent.	Indigo Produced. Seers per 100 Maunds Green Plant.
1898.							
17 Aug.	Rajkund ...	32 Tank	11·20	60·25	10·52	56·60	11·56
,, ,,	,, ...	36 ,, ...	12·55	61·25	11·75	57·60	12·94
,, ,,	,, ...	37 ,, ...	14·10	55·80	13·25	52·45	15·56
4 Sept.	,, ...	Second cake ..	13·55	57·50	12·74	54·05	—
2 Oct.	Rajpore	R 55	2·10	64·00	1·97	60·15	7·00
,, ,,	,, ...	H 63	2·94	68·60	2·72	64·50	6.50
,, ,,	,, ...	P 42	2·80	63·30	2·63	59·40	5·50
,, ,,	,, ...	J 35	8·14	59·30	7·61	55·75	8·00
9 Sept.	Ramcollah ...	31	4·75	68·85	4·41	64·65	10·00
,, ,,	,, ...	H. No. 12	6·26	68·30	5·82	64·20	10·00
,, ,,	,, ...	G. No. 16	7·24	70·20	6·76	66·00	11·50
16 Dec.	Seeraha	M & H / P 80	13·63	59·85	12·78	56·20	—
,, ,,	,, ...	,, 84	10·90	59·65	10·24	56·00	12·75
,, ,,	,, ...	,, 140	5·86	66·45	5·45	62·40	—
,, ,,	,, ...	,, 150	11·19	60·15	10·43	56·50	11·56
,, ,,	,, ...	M & H / S 5	16·36	49·75	15·32	46·70	—
,, ,,	,, ...	,, 38	5·45	61·90	5·07	58·10	—
,, ,,	,, ...	,, 132	3·56	68·10	3·29	64 00	—
30 July	Singhia	Singhia 25	4·47	72·80	4·13	68·45	9·50
,, ,,	,, ...	Chuckdowlit 24 ...	5·00	69·85	4·70	65·60	8·00
,, ,,	,, ...	Nawada 27	3·69	69·45	3·38	65·25	6·88
,, ,,	,, ...	Powra 13	3·30	71·85	3·10	67·50	8·38
26 ,,	Tatareah ...	1st cake	2·12	71·60	1·99	67·30	—
27 ,,	,, ...	T8 sound	8·76	60·70	8·17	57·05	—
,, ,,	,, ...	T8 bucra	9·25	63·00	8·69	59·20	—
27 Sept.	,, ...	2nd cake AC / T No. 28	2·12	71·80	1·99	67·50	—
1899.							
24 Jan.	,, ...	AC / T No. 28	2·10	71·05	1·97	66·80	—
1898.							
30 Sept.	Turcouleah ...	O 13	4·24	65·35	3·94	61·40	9·00
,, ,,	,, ...	K 16	11·50	57·30	10·81	53·75	13·81
,, ,,	,, ...	TT 24	6·18	65·05	5·73	61·10	15·00
,, ,,	,, ...	T 104	3·94	63·10	3·66	59·20	6·50
,, ,,	,, ...	C 37	6·95	65·00	6·48	61·10	14·50
,, ,,	,, ...	G 81	5·95	68·25	5·54	64·10	7·31
,, ,,	,, ...	H 20	4·06	67·00	3·76	63·00	10·94
,, ,,	,, ...	H 50	3·03	64·45	2·82	60·55	11·12
,, ,,	,, ...	H 106	3·33	63·75	3·10	59·85	8·75
,, ,,	,, ...	J J 20	5·56	62·05	5·17	58·30	9·75
,, ,,	,, ...	,, 50	3·82	66·80	3·57	62·80	10·50
,, ,,	,, ...	,, 80	3·04	66·95	2·82	62·90	9·00
,, ,,	,, ...	M 20	7·79	62·15	7·23	58·35	9·13

TABLE XIII.—ANALYSES OF INDIGO—*continued.*

Date Received.	Concern.	Description or Mark.	Calculated on the Dry Samples.		Calculated on Samples containing 6% Water.		Indigo Produced.
			Ash. per cent.	Indigotin, and Indirubin. per cent.	Ash. per cent.	Indigotin, and Indirubin. per cent.	Seers per 100 Maunds Green Plant.
1898.							
30 Sept.	Turcouleah ..	M 50	5·23	66·80	4·88	62·80	7·70
,, ,,	,, ...	,, 100	3·47	71·75	3·19	67·40	6·20
,, ,,	,, ...	D 20	4·54	67·30	4·23	63·25	9·81
,, ,,	,, ...	,, 50	4·10	65·40	3·85	61·45	12·62
,, ,,	,, ...	,, 89	3·89	68·75	3·57	64·55	9·20
,, ,,	,, ...	S.S 18	5·20	66·75	4·88	62·70	13·00
,, ,,	,, ...	,, 50	3·20	69·45	3·00	65·25	11·25
,, ,,	,, ...	,, 75	3·96	69·65	3·66	65·40	8·38

In many cases the samples were received wet, so, for the sake of uniformity, I have made all the calculations on the perfectly dry indigo. At the same time, the tables also show the results on the samples containing 6 per cent. of water, which may be considered a fair average for indigo in its natural condition. Whenever possible I have inserted the yield of indigo obtained in seers per 100 maunds of plant. The figures show the yield of indigo for the particular dates on which samples were taken, and must not be taken as averages for the whole season. Unfortunately, as I understand, the weights submitted are "calculation" weights, and in some cases may differ considerably from the actual amount of indigo produced. In some cases the percentage of colouring matter in the samples is in the inverse ratio of the produce, but there are numerous exceptions. There is not at present sufficient data available to account for the great differences. At some factories it may be due to the process of manufacture, or it may be due to the water; but I am firmly of opinion that the chief cause of the variations in produce and in quality is to be found in the plant itself.

As already pointed out, the variable amount of leaf on the plant is sufficient to account for much difference, and the leaf itself contains much more available colouring principle in some instances than others. In order to arrive at any definite and satisfactory results it will be necessary to make experiments over an extended time at a factory or factories, and to have responsible persons in charge of the different stages of the process.

Experimental Vats.—As mentioned in my report of the 26th September, 1898, I made a number of tests with the assistance of a "Mistri" from Doudpore, in the small iron experimental vats. For various reasons, the results were not of a very satisfactory character. The indigo produced was of a bad colour, due partly to iron and to the presence of vegetable matter, which had not been removed in straining. With other important work in hand it was impossible to give as much time and attention to these tests as was desirable, and the want of a reliable and trustworthy assistant was much felt. Experiments of this character cannot be left in the hands of natives, and in attempting to attend to them myself, and at the same time to conduct research work in the laboratory, both suffered and time was to some extent lost. At the time the experiments were made the temperature was comparatively low, averaging about 80°F., and the most important results obtained were those showing that at such temperatures plant required steeping for a much longer time than was usually practised. Plant from Moosheri steeped in the usual way at 82°F. for twelve hours gave only five seers of 60 per cent indigo per 100 maunds, whilst the same plant steeped for twenty hours under otherwise identical conditions gave eleven seers per maund. Better results were obtained by adding nitrate of potash to the water, and a considerable increase of produce (*i.e.*, of actual colouring matter) was given by the addition of ammonia to the beating vat.

Experiments in small Vat[s]

Assistance required.

Long Steepin[g] in cold weather necessary.

Experiments with samples from Barrah and Motihari.—From these two concerns I received complete series of samples of soil, plant, water, refuse water, and indigo, for investigation. Detailed analyses of these samples appear under the respective headings, and Table XIV. contains a summary of the results. In the Marripore series the plant was cut at Marripore, and the indigo made at Jugowleah factory with Jugowleah water. The indigo made at Gondrah is of superior quality to the Marripore-Jugowleah indigo, but if my samples of plant were representative there should be a greater produce in the latter case. Unfortunately, these figures have not been submitted to me.

Barrah and Motihari Experiments

Coventry's Process.—In accordance with a resolution passed at a meeting of the Association in Mozufferpore, held on the 10th September, 1898, I went to Dulsing Serai on the 16th September to inspect Coventry's process of indigo manufacture. As previously mentioned the time at my disposal was far too short

Coventry's lime and aci[d] process.

TABLE XIV.—SUMMARY OF RESULTS OF BARRAH AND MOTIHARI EXPERIMENTS.

	Barrah.		Motihari.	
	Gondrah. Average of Zerat and Dehat.	Marripore soil and plant, Ingowleah water.	Motihari.	Bhelwa. Average of heavy and medium soil.
Soils :—				
In 100 parts. Nitrogen	·085	·039	·115	·092
Phosphoric acid	·105	·110	·090	·105
Potash	·325	·460	·450	·420
Lime	21·650	20·850	21·860	1·240
Magnesia	1·930	·950	1·60	·360
Plants :—				
Percentage of leaf	37	38	—	58
In 100 parts of green leaf. Nitrogenous matters ...	7·35	9·02	7·17	8·17
Containing nitrogen ...	1·16	1·42	1·13	1·27
Matter soluble in water	8·50	8·84	9·00	7·51
Total mineral matter ...	2·82	3·66	2·91	3·68
Phosphoric acid	·229	·191	·182	·298
Potash	·658	·656	·498	·464
Lime	·725	1·023	·890	1·315
Magnesia	·378	·320	·432	·336
Yield of indigotin ...	·440	·520	—	—
Waters :—				
Grains per gallon. Total solid matter...	12·32	11·20	11·20	8·70
Alkalinity	8·70	7·84	6·72	6·30
Hardness	6·50	6·10	6·00	6·00
Seet Waters :—				
Grains per gallon. Total solid matter...	260·50	280 00	347·20	282·20
Indigotin	1·05	1·68	1·40	1·61
Indigotin equal to pounds of 60% indigo per 1000 cubic feet	1·56	2·50	2·10	2·40
Indigo :—				
Percentage of indigotin... ...	65·68	59·65	64·85	62·80
Seers of indigo produced per 100 maunds of plant	—	—	10	10

and the season too advanced to enable me to form an opinion regarding the actual amount of colouring matter obtainable by the process in comparison with the ordinary process. The principle of the process is undoubtedly sound and the indigo obtained is of excellent quality. The indigo produced is usually very rich in indigo-red or indirubin, which, as I have already explained, is the invariable result when the liquid obtained

ddition of lkali.

in steeping is treated with an alkali, such as soda, ammonia, or lime. An objectionable feature about this process, as now carried out, is that the amount of indirubin obtained is a variable quantity, and it is important that dyers should be supplied with indigo of a regular composition and quality. I believe, however, by further research that this difficulty of irregularity could be overcome.

Colouring matter obtained.

The most important question to be solved in connection with this matter, is whether an increased amount of colouring matter is obtained by the process, or whether it results in a loss. The amount of commercial indigo produced, taken alone, is little or no criterion, but the quality must also be taken into consideration.

Experiments on large scale.

On the 17th September two ranges of vats were filled with plant; one range was worked in the ordinary way, and the other according to Coventry's process. On the following day samples were taken at various stages for analysis, and experiments were also made on a small scale with some of the indigo solution. The vats were again filled with plant, and the two processes again worked simultaneously. Owing to heavy rains and floods, which occurred in the early part of September, and to the comparatively low temperature of the air and water, the produce in both cases was considerably below the average. On the large scale the following results were obtained:—

RESULTS OF EXPERIMENT No. I.

Process.	Contents of Vats. Cubic feet.	Weight of Green Plant. Maunds.	Weight of Indigo Obtained. Calculated Weight.		Percentage of Indigotin and Indirubin (with 6% of water).
			Total Seers.	Seers per 100 Maunds of Plant.	
Ordinary	7175	1112·38	45	4·04	51·32
Coventry's ...	6542	860·41	18	2·09	68·25

Yield of Indigotin obtained.

According to these figures the ordinary process yielded 2·07 seers of pure colouring matter per 100 maunds of green plant, and Coventry's process 1·43 seers per 100 maunds. It was observed, however, that after boiling up the "mal" obtained in the latter case with acid, the indigo did not settle readily (as it does usually) and the waste acid water evidently contained some colouring matter in suspension.

t Water. The "seet" water (from beating vat) contained more colouring matter from the "ordinary" range than that from the "patent range of vats. The former held in suspension 2·42lb. of pure indigotin per 1000 cubic feet and the latter 1·43lb. In working Coventry's process, a certain loss of colouring matter must

d. necessarily occur in the intermediate precipitating vat. In the above experiment the mud left after running off the clear liquid from the "precipitator" measured 4·4 per cent. of the total contents. This was considered to be an excessive amount; usually I understand the mud is not more than half that quantity. The mud in this case contained 5·88 per cent. of solid matter, and it contained a larger proportion of indigotin than the supernatant clear liquor. It was evident that colouring matter was precipitated, probably on account of too much lime having been used. In this particular instance at least 10 per cent. of the total amount of colour was left in the mud. Experiments made on a small scale with about two gallons of the liquor obtained from one of the steeping vats gave superior results by the "patent" process. In these cases no colouring matter was lost; the whole amount produced being collected and determined. The ordinary process—that is, beating direct—gave indigotin in the proportion of 4·5 seers per 100 maunds of plant, and after the addition of lime 5·8 seers per 100 maunds were obtained. In connection with these experiments, I should point out that on a small scale I have never obtained satisfactory results by direct beating or oxidation, and have invariably found, as previously mentioned, that the addition of an alkali was decidedly beneficial.

The results of the second experiment on the large scale are contained in the following table:—

RESULTS OF EXPERIMENT No. II.

Process.	Contents of Vats. Cubic feet.	Weight of Green Plant. Maunds.	Weight of Indigo obtained. Calculated weight.		Percentage of Indigotin and Indirubin (with 6% of water).
			Total Seers.	Seers per 100 Maunds of Plant.	
Ordinary	7175	1090·02	36·75	3·38	50·29
Coventry's ...	7471	973·15	27·00	2·77	81·30

These results are just in the reverse order of those obtained in the first experiment. By the ordinary process 1·70 seers of pure colouring matter were obtained from 100 maunds of plant, and by Coventry's process 2·25 seers per 100 maunds.

Further Experimen necessary.

I should like it to be clearly understood that the weights of plant and indigo produced in the above-described experiments were those submitted to me, and that it was scarcely possible for one to watch all the various stages during the whole process of manufacture. As I mentioned in my report of the 26th September last, in order to enable me to form a definite opinion as to the amount of pure colouring matter actually obtained from equal quantities of plant by Coventry's process in comparison with the ordinary process, it will be necessary to spend some weeks in the investigation, and to have capable assistants watching the operations at all the various stages of manufacture.

Summary.

In order to arrive at any definite conclusions regarding the cultivation and manufacture of indigo, much more experimental work is required. The investigation so far clearly shows there is much scope for improvement. Both in the cultivation of the plant and in the manufacture of the dye from the plant much remains to be done. Planters themselves can help materially in the inquiry by affording information gained by their own experience. It is hoped that the details of analyses and experimental work given in this report will appeal to planters and be the means of eliciting inquiries upon various matters which will be of service to the investigator.

As regards cultivation, it has been shown that plant varies very greatly in its composition. Some samples contain much more of the colour-giving principle than others. By selecting the most suitable soils and by the application of fertilisers the amount of obtainable colour can no doubt be greatly increased. For the vigorous growth of the plant an abundance of nitrogen is evidently required. Although nitrogen is probably taken in from the atmosphere, there seems every probability that the application of nitrogenous fertilisers would act beneficially; in fact this is already shown by the known advantages of using refuse plant or "seet." In the manufacture of indigo from the plant, the most important point to be considered is the best means of extracting the colour-giving principle, and at the same time to prevent its decomposition into worthless products, which under certain conditions takes place with the greatest facility. The extraction would be greatly facilitated and the operation would be much more uniform if the leaves only were treated. The stems contain no colour-principle, and they yield to water matter of an objectionable character. It has been shown that plant varies very greatly as regards the proportion of leaf and stem constituting it, and this variation must necessarily account in a great measure for the great differences in the indigo produced both as regards quantity and quality. Another important point is the addition of substances to the beating vat, with a view of preventing the destruction of the colour-yielding body, and of accelerating the formation of indigo-blue. The conversion takes place most readily in an alkaline solution, and it is on these lines that I intend to carry out my first experiments. It would fulfil no useful purpose if I were to enter here into details regarding the experiments which I propose to make. On the contrary, it could only tend to defeat the ends which the Association has in view.

The question as to the most suitable water for use in manufacturing indigo requires further research, but the absence of organic impurities appears to be of greatest importance.

The refuse or "seet" water which is run off from the beating vat contains an appreciable amount—sometimes more, sometimes less—of colouring matter, and the recovery of this waste is worthy of consideration. In order to compete more successfully with artificial dyes—particularly with synthetic indigo—I have shown that from a dyer's point of view the whole operation of pressing, cutting, and slow drying could be dispensed with and the indigo supplied to consumers in a powdered state. I have pointed out, however, that this course would not be advisable having regard to the present method of selling indigo. If the whole of the planters combined to form one company concern and arranged to sell direct to consumers, the best form of putting the indigo on the market would then, in my opinion, be in a powdered state. All indigo thus sold should be guaranteed to contain a certain percentage of colouring matter.

I am afraid that some of the planters of Behar may have been disappointed with the results of the year's work, but the task set me, with all the attendant difficulties of pursuing chemical research in such a climate as India, was a formidable one. There is really plenty of useful work to do for a number of chemists. If I may be allowed to draw attention to a somewhat parallel case, I would cite that of the production of artificial indigo. Artificial indigo was discovered by A. Baeyer as long ago as 1880, but numerous chemists have been devoting all their time to the problem of producing it on anything like a commercial scale for nearly twenty years. At the present time a great number of German chemists are still working at this problem in some of the finest and best-equipped chemical laboratories in the world. The amount of money spent in this research has been enormous.

In conclusion, I wish to express my hearty thanks to the many planters and others who have rendered me assistance by furnishing information, and by making inquiries regarding the subject I have taken in hand; also for the hospitality I received and the many kindnesses shown me during my sojourn in India. Undesirous as I am of mentioning names among so many, I would particularly like to express my indebtedness to the secretary and hon. secretary of the Association for all they have done to help me in my work.

I am, Gentlemen,

Yours faithfully,

CHRISTR. RAWSON.