horizon of well-drained paddy soils may exist in the oxidized form even during the irrigation season. In the furrow slice of a heavily degraded paddy soil, however, certain kinds of soil organic substances may become soluble because of the lack of ferrous ions to precipitate such substances out of solution. These soluble organic compounds may be absorbed by the precipitated ferric compounds, when they are washed down into the upper portion of the B horizon. Then, under flooded conditions this upper layer of the B horizon soon will begin to show a reduced condition, the iron in it will become soluble and will be eluviated to lower depths. Thus, this upper layer of the B horizon gradually acquires the characteristics of the A horizon as it is subjected to the eluviating action of the soil water. Although the free ferric oxide in the horizon designated as the B horizon in Table 21 appears to have come from the overlying A horizon, some of which was formed during gleization may have ascended from the lower layers with the rise and fall of the water table.

Recenty Shioiri and Yokoi worked on this problem giving special attention to the influence of excess H_2S on peptise action upon colloidal ferrous sulfide, and found that the downward leaching of Fe compounds out of degraded rice soils under flooded conditions is attributable to the presence of excess H_2S in the soil water. (Shioiri, M. and Yokoi, H.: The leaching mechanism of iron sulfides in degraded rice soils. J. Sci. Soil, Japan 20: pp.157-161, 1950)

3. Distribution of degraded paddy soils.

a. It is estimated that not less than 10 percent of the paddy soils of Japan is of the degraded type. From many field observations, it has been observed that these unproductive paddy soils have been degraded largely because of the kind of parent material resulting in the formation of such soils, whether alluvial or residual soils. The parent materials which have contributed most to the formation of degraded paddy soils are from regions of acidic igneous rocks such as granite, quarz-parphry, and liparite and also from regions where the following sedimentary rock formations are found: rocks of the Chichibu Paleozoic era (Permian and Carboniferous) and the rocks of the Arakawa series (Senoniam epoch) of the Cretacious period in the Mesozoic era. Of these rocks, those of volcanic origin are of acidic nature and those of sedimentary origin are of silicious marine deposits. In addition, degraded paddy soils are often formed from sandy lagoon deposits and sandy materials transported from regions where grantic geniss is found.

b. From these observations, it seems that soils derived from silicious materials usually have a tendency toward degradation under the usual conditions of rice culture. It is significant that no degraded paddy soil has been found which has originated from parent materials transported from regions of neutral or basic igneous rocks.

4. Reclamation of degraded paddy soils.

a. In certain districts where many degraded paddy soils are found farmers learned a long time ago by experience that rice production can be improved greatly by applications of mud deposits from rivers, ditches, and reservoirs. Even applications of soils from hills or cropped uplands have shown significant responses in this respect. Farmers also have found that after growing lotus on degraded paddy soils, they were able to experience good rice yields for several years. The good effects are believed to result from the mixing of the soil of the B horizon with the soil of the furrow slice during the cultivation of lotus.

b. Two methods of improving the productivity of degraded soils are recommended and are similar to practices already employed by farmers. The first method is to apply mud deposits taken from beds of rivers, lakes, or reservoirs. Likewise, applications of virgin soils which contain much free iron oxide and active manganese compounds have shown favorable responses. The rate of application is from 100 to 200 metric tons per hectare. The other method of improvement recommended is to mix the subsoil with the surface soil by deep plowing.

G. Colloidal behavior of paddy rice soils under flood conditions.

1. Previously, it has been shown that iron is eluviated from the furrow slice in the form of Fe^{++} ions or in soluble compounds into the iron-accumulation layer (plow-sole or subsoil) where oxidation to the ferric form results, some of the oxidation probably is due to the oxidizing action of MnO_2 accumulated in the B horizon. After being oxidized, the iron precipitates out of solution mostly as ferric hydroxide. If this is true in paddy soils, it is reasonable to expect the existence of a low electrokinetic potential difference (zeta potential) in the soil colloids of the reduced layer of the furrow slice of flooded paddy soils. It is known that Fe^{++} ions in solution are capable of depressing the zeta potential of negatively charzed soil colloidal particles under conditions of a neutral or weakly acid reaction. 33/ Considering the above-mentioned assumptions, the velocity of cataphoresis of soil colloids from paddy soils was determined under conditions of reduction and oxidation. 29/ These experiments were conducted as follows:

a. Soil samples were taken from a paddy field at the Agricultural Experiment Station, Konosu, Saitma Prefecture, and from a lysimeter tank which was flooded throughout the year, at the Agricultural Experiment Station, Nishigahara, Tokyo. Distilled water was added to the wet samples in the ratio of 100 cc of water to 30 grams of dry soil. The submerged samples were incubated at 28° C for one month under either oxidative or reductive conditions. The wet samples incubated under an oxidative condition were placed in a shallow glass vessel and covered with distilled water. In order to prevent the formation of a reduced layer in these samples, the depth of the soil layer was kept at approximately 3 mm. The samples incubated under reductive conditions were placed in glass cylinders of 50 cc capacity, each equipped with a rubber stopper which had one short glass tubing and one long glass tubing. The short tube expanded to the bottom of the stopper and served as an inlet for nitrogen gas or air while the long tube extended deep into the cylinder and served as an outlet for transferring the soil suspension into the apparatus for determing the velocity of cataphoresis. After the samples were covered with distilled water, leaving a air in the cylinder, the glass tubings were sealed with "ski" wax. In the preparation of the soil suspension, the stoppered cylinders were firest shaken by hand and then were centrifuged. The transfer of the centrifuged suspension to the apparatus for determining the velocity of cataphoresis of suspended soil colloidal particlos was made by piercing each wax seal of the tubes with the warmed ends of thin glass tubings drawn out to capillarity. The soil suspension in the cylinders then was forced, with air pressure by blowing through the short tube, up the long tube, into the thin glass tubing and into the apparatus.

b. The apparatus used to measure the velocity of cataploresis of the suspended colloidal particles is a modification(a) of the Kruyt and van Arkel cell. 14/ In order to avoid too much dilution of the soil sample, which results in a marked increase in the cataphoretic velocity of soil colloids, the ratio of soil to water was determined after several trials.

The endoosmotic velocity of the water at the surface of the upper and lower glass walls of the apparatus was calculated using Smolkowsky's formula.(b)

(a) Constructed by S. Nishigaki, Soils Department, Tokyo University.

(b)

$$U = Uo \left(1 - 6\left\{\frac{x}{d} - \left(\frac{x}{d}\right)^2\right\}\right. \text{ and } u' = u + U$$

"U" is velocity of water at depth "x", "Uo" velocity of water at upper and lower glass walls. "d" is depth of cell.
"u' " is observed velocity of colloidal particle at depth "x" "u" is cataphoretic velocity of colloid particle.

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2. The results of these investigations, as shown in Table 23, are summarized as follows:

a. The cataphoretic velocity of soil colloidal particles is slow in both the oxidized and reduced suspension.

b. The endoosmotic velocity of the water at the surface of the upper and lower glass walls of the apparatus was slow in the case of oxidized suspension.

3. The best explanation of these results is the presence of Fe ions in the suspension. As mentioned earlier, the Fe^{++} ion is able to decrease the zeta potential of the soil colloids and the glass of the apparatus which are both charged negatively. In the case of an oxidized soil, the Fe^{++} ion is oxidized to the Fe^{+++} ion and is precipitated as ferric hydroxide. The ferric hydroxide may depress the zeta potential of negatively charged soil colloids. However, a suspension prepared from an oxidized soil does not markedly depress the zeta potential of the glass of the apparatus because the water contains no Fe ion.

4. Since these experiments were carried out without any percolation of water through the soil, it is not entirely correct to assume that identical conditions exist in the soil colloids under actual field conditions. However, these results can serve as the basis for further research on the chemistry of paddy soils.

5. The low zeta potential of colloidal particles in a flooded soil suggests that a microbial equilibrium, although unstable, can be easily attained in flooded soils because of the likelihood that the negative zeta potential of bacterial cells may be depressed as in negatively-charged soil colloids. For example, under a constant temperature the microbial activity in flooded paddy soils, as measured by ammonium-nitrogen production, ceases or falls off markedly two or three weeks after flooding.

6. From a study of the colloidal properties of flooded paddy soils, it is possible to obtain a clear picture of the development of the profile of paddy soil, especially the nature of the eluviation and illuviation of iron, manganese, and organic matter. In addition, the leaching of NH_4^+, K^+, and other cations from the soil of the furrow slice also can be explained from a study of the zeta potential of soil colloids.

H. Soil drying and rice production.

1. Russel referred to the beneficial effects of soil drying on crop production. 18/ The beneficial effects on rice production of drying paddy soils between two successive rice crops have been known in Japan for a long time. Farmers often have dried the mud obtained from lakes, rivers, ditches, or irrigation canals and applied it to their fields.

2. A previous discussion (Section A-4) showed that air-drying the soil of a paddy field prior to irrigation gives an increased production of ammonium-nitrogen within two weeks after flooding and also results in an increased availability of soil phosphoric acid as shown in Table 5. Since the ammonium-nitrogen produced is well distributed in the soil of the furrow slice, it is absorbed almost completely by the rice crop and there is no significant loss through denitrification at the surface of the furrow slice. This is quite well substantiated by the results of a field experiment described in the following paragraphs. 22/

3. In order to determine the effects of soil drying on rice production under actual field conditions, the following experiment was carried out at the Agricultural Experiment Station, Konosu, Saitama Prefecture, during 1940. Eight plots were chosen each measuring about 30 square meters. Each plot was divided into three equal parts and the soil of each part was subjected to the following degress of air drying before irrigation: well-dried, moderate, and none.

The results of this experiment are given in Table 24 and are expressed in yields of brown rice and straw and in the amount of nitrogen absorbed by the crops. Table 25 given data on the ammonium nitrogen content of the furrow slice at the following intervals after the plots were flooded: 3 days, 14 days, and 29 days. On 11 April of the following year, the effect of air-drying, prior to flooding, on ammonium-nitrogen production in the soil of each plot was determined in the laboratory. This is also included in Table 25. The results of this experiment are summarized as follows:

a. Air-drying the soil of the furrow slice prior to flooding results in an increase in ammonium-nitrogen in the soil and in an increased yield of rice.

b. On the average, the difference between the nitrogen contents of the rice crops harvested on the well-dried and non-dried plots corresponds closely to the difference in the ammonium-nitrogen contents of these plots 14 days after flooding.

c. The rice crops grown on well-dried soils absorbed on the average 23.0 Kg of nitrogen more per hectare than the crop grown on soils that were not air-dried. When the ammonium-nitrogen production in these two groups of soils was measured in April of the following year, it was found that the non-dried soils produced an average of 2 mg more nitrogen per 100 grams of air dry soil than the well-dried soil. If the weight of a furrow slice (0-10 cm) is taken as 1,000,000 Kg of air dry soil per hectare, 2 mg of nitrogen per 100 grams correspond to 20.0 Kg of nitrogen per hectare. From these calculations and comparisons, it is apparent that the ammonium nitrogen produced by the drying of paddy soil is nearly all absorbed by the rice crop. Although this experiment showed that soil drying produces the amount of nitrogen available for the next crop, it is believed that there is no need of fear that soil drying every year will reduce subsequent rice yields because of the reasons mentioned in previous paragraphs (Section D and E).

1. Potential availability of soil nitrogen in paddy rice soils. <u>20/</u>

(1) Section C of this paper shows that drying and temperature act separately on the ammonium-nitrogen production in paddy soils. By measuring the ammonium-nitrogen production in air-dried soils incubated at a specific temperature for a certain interval, the availability of soil nitrogen in various soils can be determined and compared. In addition, by measuring the ammonium-nitrogen production in wet and in air-dried samples incubated at the same temperature, the drying effect on ammonium-nitrogen production can be determined with considerable reliability.

2. In order to determine the availability of nitrogen in the paddy soils of Japan, soil samples were taken from the furrow slice of paddy fields of many prefectural agricultural experiment stations. The production of ammonium-nitrogen for each sample was determined. The paddy fields from which the samples were taken had been fertilized each year. Sampling was done in April for the fields that had no winter crops. Double-cropped fields were sampled immediately after harvesting of the winter crop which usually was wheat or barley. The results of this study are presented in Table 26. The following generalizations are made from these data:

(a) The ammonium-nitrogen production of soils from paddy fields cropped also during the winter generally is less than that of soils from paddy fields which remain uncropped throughout the winter. In contrast to upland soils, a reduced layer develops under flooded conditions in the soils from double-cropped