Technical Papers

DDT as a Marine Antifouling Agent[1]

JOHN F. MARCHAND

Laboratory of Physiology, Yale University School of Medicine, New Haven, Connecticut

In connection with the testing of dichlorodiphenyltrichloroethane as an insecticide it was noted that this substance has physical and pharmacological properties which might make it effective as a marine antifouling agent. Its insolubility in water would prevent it from being washed away by the ocean, while its lipoid solubility would permit it to be absorbed by sessile marine organisms, all of which do have some lipoid material distributed through their tissues. The high toxicity of DDT for insects suggested that cirripeds and other members of the phylum Crustacea might be similarly affected and controlled if the substance could be utilized as a growth inhibitor.

The following experiments were made to test the applicability of DDT for antifouling purposes:

(1) On 15 June 1945 a panel (one foot by three feet) on the bottom of a rowboat was painted with a coat of pure white lead and linseed oil. On the opposite side of the keel a similar panel was covered with a coat of the same paint with the addition of 20 per cent DDT by weight. The finish was allowed to dry, and the boat was launched in Narragansett Bay, Rhode Island, on 20 June. When the boat was removed from the water on 1 September, the area covered by white lead and linseed oil had become the site of attachment of several hundred *Balanus balanoides*. The paint containing DDT accumulated no barnacles at all. Both the control paint film and the DDT paint withstood the action of the sea water and were in rather good condition at the end of this experiment. An area covered by red copper bottom paint remained free of barnacles.

(2) An old iron-bound keg was painted with a series of longitudinal test strips on 15 June 1945 and anchored just below the surface of Narragansett Bay on 20 June. These strips were painted with: (a) white lead and linseed oil; (b) white lead and linseed oil with 20 per cent DDT; (c) DDT alone—a thick visible film left by the evaporation of ethyl acetate; and (d) commercial red copper paint. In addition, there was an unpainted control area. Over the period from 20 June to 20 October the growth of marine algae, particularly red and green kelp and fucus, was so abundant as to crowd out other fouling organisms with the exception of a few snails and mussels. This growth of algae was partially inhibited over the area of the red copper paint, but not elsewhere; the DDT either alone or mixed in paint had no apparent effect on the algae. Both the white lead finish and the DDT-white lead deteriorated appreciably during this experiment, each to about the same degree. The thick film of DDT alone flaked off in places but remained undissolved by the sea water. The effect of these films on barnacles could not be evaluated, although numerous large specimens of *Balanus* developed on the shaded lower end of the keg, where no protective coating had been applied.

(3) A five-foot, four- by six-inch wooden plank was painted on 15 June and anchored below the surface of Narragansett Bay from 20 June to 20 October. At the end of that time the area coated with DDT alone had accumulated many algae and bryozoans but no barnacles. The DDT film flaked off in a few places but did not dissolve away in the sea water. The areas covered by white lead paint containing 5 per cent and 25 per cent DDT both accumulated algae and bryozoans but no barnacles. The white lead paints, both with and without DDT, were in only fair condition. An area coated with red copper bottom paint collected no barnacles and relatively few algae. The unpainted control area was crowded with algae, barnacles, bryozoans, and a few oysters and mussels.

(4) One quadrant of a wooden barrel was painted with "Old Salem" white yacht paint; a second quadrant, with the same paint containing an admixture of 10 per cent DDT; and a third, with DDT in ethyl acetate until covered with a fairly thick grayish white film of DDT. The fourth quadrant was left as a control. This barrel was filled with rocks and placed upright on the bottom of the bay, just below tide level, on 20 July 1945. During the following three months all the surfaces of the barrel were overrun by snails and overgrown with algae. *Balanus* developed only on the areas untreated with DDT. The pure paint and the paint containing DDT remained in good condition up to the time of the most recent observation, on 20 October.

These observations on the effect of DDT as a marine antifouling agent appear to be in agreement with those currently reported by Dimick (*1*) in Yaquina Bay, Oregon, and Seagren, Smith, and Young (*2*) at Daytona Beach, Florida. DDT incorporated in a marine paint is effective in inhibiting the development of barnacles over the time covered by the experiments,

[1] Facilities for these experiments were made available by John R. Griffith, Saunderstown, Rhode Island.

although it does not provide effective control of other organisms which cause fouling of ship bottoms. It does not wash away in sea water over a four-month period, and it retains its effectiveness when incorporated as a constituent of paint. Admixture of DDT does not appear to have an adverse effect on the drying properties or durability of the paint. These experiments suggest that an ideal ship-bottom finish could combine the more general effectiveness of copper bottom paint with the relatively specific antibarnacle effect obtainable with an admixture of DDT.

References

1. DIMICK, R. E. *Science,* 1945, **102**, 10.
2. SEAGREN, G. W., SMITH, M. H., and YOUNG, G. H. *Science,* 1945, **102**, 425.

The Therapeutic Effect of Folic Acid in Tropical Sprue[1,2]

TOM D. SPIES, *Hillman Hospital, Birmingham, Alabama,* and RAMON M. SUAREZ, RAMON M. SUAREZ, JR., and F. HERNANDEZ-MORALES, *School of Tropical Medicine, San Juan, Puerto Rico*

The discovery that folic acid is an effective substance in the treatment of pernicious anemia and nutritional macrocytic anemia marks the culmination of an epoch in the study of these diseases. The present report demonstrates that folic acid benefits persons with tropical sprue.

Folic acid is a substance which is present in small amounts in liver, yeast, and other foods. The study of Spies and his associates (*1, 2*) showing that there is a remarkable response of improvement in the blood picture of persons with Addisonian pernicious anemia, nutritional macrocytic anemia, and the macrocytic anemia of pregnancy, of pellagra, and now of tropical sprue reveals the close relationship existing between the field of hematology and that of nutrition. These new discoveries promise to open a new era for the study of the pathogenesis of the various types of macrocytic anemia.

Macrocytic anemias occur throughout the world. Addisonian pernicious anemia occurs more in temperate zones and sprue in the tropics. The *British Medical Journal* (*3*) has recently stated that the British Empire is the world's largest reservoir of nutritional macrocytic anemia and sprue.

In order to cooperate in a study of sprue in the tropics the senior author accepted the invitation of Drs. Morales Otero and Ramon M. Suarez to form a cooperative study between the University of Cincinnati and the School of Tropical Medicine, San Juan, Puerto Rico. From a number of emaciated patients who had glossitis and diarrhea, and who passed light-colored, bulky, and frothy stools, we chose and hospitalized five patients. The criteria used in their selection were as follows: (1) The patient must have macrocytic anemia as determined by Wintrobe indices. (2) The bone marrow must show the typical erythroblastic arrest seen in macrocytic anemia. (3) The erythrocyte counts must be below 2,500,000. (4) The patient must be untreated, or he must not have been treated recently enough to interfere in any way with our evaluation of the effect of folic acid. (5) He must have persistently low reticulocyte counts during the period of observation. (6) He must have glossitis, and diarrhea characterized by fatty stools.

TABLE 1

ANTIANEMIC EFFECT OF FOLIC ACID IN TROPICAL SPRUE

	RBC (millions)		Hg. (grams)		Reticulocytes (%)			Dosage of Folic Acid			
Case No.	Initial day	Final day	Initial day	Final day	1st day of rise	Day of peak	% at peak	Daily dosage mg.	No. of days	Total mg.	Diet
1	.6	2.25	2.4	7.5	4	5	18	50	18	900	No meat products or yeast
2	1.0	2.02	4.9	6.9	5	6	25.4	50	14	700	
3	1.7	2.48	8.4	10.1	3	5	17.0	50	14	700	
4	2.3	2.5	10.1	11.0	3	4	7.8	50	12	600	
5	2.1	2.7	9.9	10.1	4	7	21.2	50	8	400	Meat allowed

Four of the patients were restricted to a diet devoid of meat, kidney, yeast, liver, and other meat products. Case 5 received some meat and meat products.

Following the oral administration of folic acid, the clinical improvement of the patients was so striking that all observers noticed on the third or fourth day an increase in the sense of well-being, strength, and

[1] University of Cincinnati Studies in Nutrition at San Juan, Puerto Rico, in cooperation with the School of Tropical Medicine, San Juan. Technical assistance was given by Clemencia Benitez Gautier, M. T. Expenses of the study were borne by grants from the Lederle Laboratories, Inc., which also supplied the folic acid, and the Edward Mason Williams Fund.

[2] Since the time this manuscript was submitted, Darby, Jones, and Johnson (*J. Amer. med. Ass.*, 1946, **130**, 780) and Moore, Bierbaum, Welch, and Wright (*J. lab. clin. Med.*, 1945, **30**, 1056) have shown the effect of synthetic *L. casei* factor on three cases and one case, respectively, of nontropical sprue. Spies, Lopez, Menendez, Minnich, and Koch (*S. med. J.*, 1946, **39**, 30–32) and Spies, Milanes, Menendez, Koch, and Minnich (*J. lab. clin. Med.*, 1946, **31**, 227–241) have shown the effect of synthetic *L. casei* factor on three and nine cases, respectively, of tropical sprue. In every instance the findings are similar to those reported in this paper.