Transactions of the National Academy of Science and Technology Philippines (Transactions NAST PHL)

is published by the National Academy of Science and Technology Philippines once a year.

Open Access: Published papers may be downloaded freely and printed for individual and non-

commercial use only but not to be posted on other websites.

Copyright: Authors retain the copyright of their respective papers.

Aims and Scope: This journal serves as the proceedings of the annual scientific meetings (ASM) of NAST

PHL. The ASMs are a leading forum for the presentation of scientific and policy research outputs which address issues and concerns relevant not only in the Philippines but in other countries of the world as well. All papers are invited and the authors are known experts in their fields. The ASM's Program/Steering Committee selects the topics and

speakers.

Starting with Volume 43 (2021), this journal will continue to publish selected papers from the ASMs and will be open to contributions from the global scientific community in all fields—agricultural sciences, biological sciences, engineering science and technology, health sciences, mathematical and physical sciences and social sciences. The types of papers this journal will publish include the following: plenary papers presented at NAST PHL Annual Scientific Meetings, perspectives/commentaries, original articles, review articles, feature articles, brief reports, and biographical essays of members of NAST PHL and other outstanding men and women of science. All contributed papers will be subjected to double-blind peer review.

The National Academy of Science and Technology Philippines

3rd Level, Science Heritage Building, DOST Compound General Santos Avenue, Bicutan, Taguig City 1631

Website: www.nast.ph; Email: secretariat@nast.dost.gov.ph

Direct Lines: (63 2) 8838-77-39/66/92

Editorial Staff

Editor-in-chief: Acd. Evelyn Mae Tecson-Mendoza

Associate Editor: Ms. Guada B. Ramos-Dimaya

Assistant Editor: Ms. Ladylove May B. Baurile

Editorial Staff: Mr. Vince Aren B. Cortez

Ms. Alyssa Kaye S. Mojar Ms. Camille D. Santos

Website Staff: Mr. Abdul Jalil Yacob

Mr. Niño Rodil

Disclaimer:

The views expressed herein are those of the authors and do not necessarily reflect the

views of NAST PHL.

FOR VOLUME 43 (2021)

EDITOR-IN-CHIEF

Acd. Evelyn Mae Tecson Mendoza

Professor Emeritus
Institute of Plant Breeding
College of Agriculture and Food Science
University of the Philippines Los Baños

EDITORS

Acd. Gisela P. Concepcion

Professor Emeritus Marine Science Institute University of the Philippines Diliman

Acd. Raymond Girard R. Tan

Professor & University Fellow Department of Chemical Engineering De La Salle University

Acd. Caesar A. Saloma

Professor, National Institute of Physics College of Science University of the Philippines Diliman

Acd. Edward H.M. Wang

Professor
College of Medicine
University of the Philippines Manila

Acd. Allan BI Bernardo

Distinguished University Professor & University Fellow De La Salle University

BOARD OF EDITORS

Acd. Benito M. Pacheco

Professor, Institute of Civil Engineering College of Engineering University of the Philippines Diliman

Dr. Claro B. Mingala

Scientist IV Philippine Carabao Center Nueva Ecija, Philippines

CM Joel L. Cuello, PhD

Professor, Department of Agricultural and Biosystems Engineering University of Arizona Arizona, USA

CM Francis L. de los Reyes III, Ph.D.

Professor
University Faculty Scholar
Department of Civil, Construction, and
Environmental Engineering
North Carolina State University
North Carolina, USA

Acd. Arvin P. Diesmos

Director, Biodiversity Information Management Unit ASEAN Centre for Biodiversity Los Baños, Laguna

Acd. Christopher P. Monterola

Professor Head, Aboitiz School of Innovation, Technology, and Entrepreneurship Asian Institute of Management

Dr. Queena N. Lee-Chua

Professor

Department of Mathematics Ateneo de Manila University

CM Annabelle P. Villalobos

Consultant, Johnson & Johnson Biopharmaceuticals, USA Balik Scientist, Department of Science and Technology

Maria Corazon A. de Ungria

Scientist II

DNA Analysis Laboratory

Natural Science Research Institute University of the Philippines Diliman

Acd. Victor B. Amoroso

Professor Emeritus Central Mindanao University Musuan, Bukidnon, Philippines

EXECUTIVE COUNCIL, NAST PHL

Acd. Rhodora V. Azanza

President

Professor Emeritus

University of the Philippines Diliman

Acd. Jaime C. Montoya

Secretary

Professor

University of the Philippines Manila

Acd. Eufemio T. Rasco Jr.

Member

Professor Emeritus

University of the Philippines Mindanao

Acd. Aura G. Matias

Member

Professor

University of the Philippines Diliman

Acd. Fabian M. Dayrit

Vice President

Professor Emeritus

Ateneo de Manila University

Acd. Reynaldo B. Vea

Member

Professor and President

Mapua Institute of Technology

National Scientist Raul V. Fabella

Member

Professor Emeritus, School of Economics

University of the Philippines Diliman

About NAST Philippines

The National Academy of Science and Technology (NAST) Philippines is the country's highest advisory body to the government and the science community on matters related to science and technology. It also has the mandate to recognize outstanding achievements in science and technology made by Filipino scientists in all fields of science. NAST PHL was established on December 17, 1976 through Presidential Decree (PD) No. 1003-A and became operational in 1978 through PD 1557.



Its Vision for the Country

A progressive Philippines anchored on science

Its Mission

- 1. To recognize scientists for their exemplary science and technology achievements, and to identify and support emerging scientific talent;
- 2. To encourage Academy members to continue their own scholarly pursuits;
- 3. To provide independent advice on the utilization of science, technology and innovation;
- 4. To promote a strong science culture in Philippine society; and
- 5. To link with national academies of science and technology in other countries.

Its Mandate

- To recognize outstanding achievements in science and technology as well as provide meaningful incentives to those engaged in scientific and technological researches (PD 1003-A, 1976);
- 2. To advise the President and the Cabinet on matters related to science and technology (EO 818, 1982);
- 3. To engage in projects and programs designed to recognize outstanding achievements in science and promote scientific productivity (EO 818, 1982);
- 4. To embark on programs traditionally expected of an academy of science (EO 818, 1982); and;
- 5. To promote and preserve science and technology resources of the country through the Philippine Science Heritage Center, which shall serve as the main repository of the country's contributions, achievements and accomplishments in science and technology (RA 9107, 2000).