


การจำลองการแพร่กระจายของมลสารอากาศเหนือบริเวณภูมิประเทศแบบไม่ใช้ที่ราบโดย
ใช้ระบบแกน 3 มิติชนิดทั่วไป



นางสาว ไพริน วิจิตรเจริญเมือง

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต

สาขาวิชาวิศวกรรมเคมี ภาควิชาวิศวกรรมเคมี

คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2544

ISBN 974-03-1343-4

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

I 2054540X

SIMULATION OF DISPERSION OF AIR POLLUTANT OVER
NON-PLANAR TOPOGRAPHY USING 3-DIMENSIONAL
GENERALIZED COORDINATE SYSTEM

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering in Chemical Engineering

Department of Chemical Engineering

Faculty of Engineering


Chulalongkorn University

Academic Year 2001

ISBN 974-03-1343-4

Thesis Title Simulation of Dispersion of Air Pollutant over Non-planar
Topography Using 3-Dimensional Generalized Coordinate
System
By Miss Pairin Vijitjaroenmuang
Field of Study Chemical Engineering
Thesis Advisor Professor Wiwut Tanthapanichakoon, Ph.D.

Accepted by the Faculty of Engineering, Chulalongkorn University in
Partial Fulfillment of the Requirements for the Master 's Degree



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ไพริน วิจิตรเจริญเมือง : การจำลองการแพร่กระจายของมลสารอากาศเหนือบริเวณภูมิประเทศแบบไม่ใช่ที่ราบโดยใช้ระบบแกน 3 มิติชนิดทั่วไป (SIMULATION OF DISPERSION OF AIR POLLUTANT OVER NON-PLANAR TOPOGRAPHY USING 3-DIMENSIONAL GENERALIZED COORDINATE SYSTEM) อาจารย์ที่ปรึกษาวิทยานิพนธ์ : ศ. ดร. วิวัฒน์ ตัณฑะพานิชกุล, 260 หน้า. ISBN 974-03-1343-4.

ในวิทยานิพนธ์นี้ แบบจำลองการแพร่กระจายของมลสารอากาศซึ่งใช้ระบบแกน 3 มิติชนิดทั่วไปร่วมกับเทคนิคCFD ถูกใช้เพื่อทำนายการแพร่กระจายของมลสารอากาศเหนือบริเวณภูมิประเทศที่ไม่ใช่ที่ราบ ความเหมาะสมของแบบจำลองได้รับการพิสูจน์โดยการเปรียบเทียบกับคำตอบเชิงวิเคราะห์ของแบบจำลองปรากฏการณ์การขนส่งสำหรับพื้นที่ราบ และข้อมูลการทดลองในอุโมงค์ลมเหนือบริเวณที่ไม่ใช่ที่ราบของ R. Ohba และคณะ สำหรับกรณีแรกแบบจำลองนี้แสดงให้เห็นว่า เหมาะกับการทำนายการแพร่กระจายของมลสารที่บริเวณห่างจากแหล่งกำเนิดมากกว่าในบริเวณใกล้เคียง ส่วนผลการเปรียบเทียบกับผลการทดลองในอุโมงค์ลมพบว่า แบบจำลองนี้เหมาะกับการทำนายความเข้มข้นตามระยะทางได้ลมที่บริเวณหน้าเขาได้มากกว่าบริเวณหลังเขาและมีความเที่ยงตรงมากกว่าในบริเวณที่มีความแตกต่างของความชันของพื้นที่ไม่มากนัก

จากนั้นได้ทำการทดลองบนคอมพิวเตอร์เพื่อศึกษาอิทธิพลตัวแปร 5 ตัวคือ ทิศทางลม ความเร็วลม สัมประสิทธิ์การแพร่กระจายในแนวระดับและแนวตั้ง และ เลขยกกำลังของกฎยกกำลังที่มีต่อความเข้มข้นเฉลี่ย 45 นาทีของ SF_6 ซึ่งแพร่กระจายเหนือบริเวณภูเขาโดดเดี่ยวโดยจำลองแบบจากเขา Steptoe Butte ในรัฐวอชิงตัน ผลการทดลองแสดงให้เห็นว่า ทิศทางลม ความเร็วลม และสัมประสิทธิ์การแพร่กระจายในแนวระดับและแนวตั้งมีผลกระทบอย่างมีนัยสำคัญต่อความเข้มข้นเฉลี่ยที่สถานีตรวจวัดส่วนใหญ่ ที่เลือก หนึ่งในเลขยกกำลังของกฎยกกำลัง มีอิทธิพลอย่างมีนัยสำคัญที่บางสถานีตรวจวัดเท่านั้น

สุดท้ายแบบจำลองนี้ถูกใช้เพื่อทำนายความเข้มข้นของฝุ่น PM_{10} เฉลี่ยภายใต้เงื่อนไขของ ทิศทางลม ความเร็วลม และ สัมประสิทธิ์การแพร่กระจายแนวตั้งต่างๆ ที่สถานีตรวจวัดต่างๆ ในบริเวณโรงโม่หินในจังหวัดสระบุรี ผลการทำนายแสดงให้เห็นว่าเมื่อความเสถียรของบรรยากาศเพิ่มขึ้นซึ่งสะท้อนให้เห็นจากค่าสัมประสิทธิ์การแพร่กระจายแนวตั้งที่ลดลง จะทำให้ความเข้มข้นของฝุ่น PM_{10} ที่ทำนายได้มีค่าสูงขึ้นที่ทุกสถานีตรวจวัด การเปลี่ยนแปลงของทิศทางลมนั้นทำให้ค่าความเข้มข้นของฝุ่นที่ทำนายได้เปลี่ยนอย่างมีนัยสำคัญ ณ สถานีตรวจวัดส่วนใหญ่ เนื่องจากความเร็วลมในพื้นที่ที่ศึกษาเป็นพื้นที่ลมสงบ(ความเร็วลมไม่เกิน 2 เมตรต่อวินาที) นอกจากนี้ในการศึกษาผลกระทบของตัวคูณอัตราการปล่อยฝุ่น พบว่าความเข้มข้นของฝุ่น PM_{10} เฉลี่ยมีค่าเพิ่มขึ้นเป็นสัดส่วนกับการเพิ่มค่าตัวคูณอัตราการปล่อยฝุ่น

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

ภาควิชา.....วิศวกรรมเคมี.....ลายมือชื่อนิสิต.....ไพริน วิจิตรเจริญเมือง.....
สาขาวิชา.....วิศวกรรมเคมี.....ลายมือชื่ออาจารย์ที่ปรึกษา.....วิวัฒน์ ตัณฑะพานิชกุล.....
ปีการศึกษา.....2544.....ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....

427046921 : MAJOR CHEMICAL ENGINEERING

KEY WORD: AIR DISPERSION MODEL / NON-PLANAR / GENERALIZED COORDINATES / AIR DISPERSION MODEL / CFD

PAIRIN VIJITJAROENMUANG: SIMULATION OF DISPERSION OF AIR POLLUTANT OVER NON-PLANAR TOPOGRAPHY USING 3-DIMENSIONAL GENERALIZED COORDINATE SYSTEM. THESIS

ADVISOR : PROF. WIWUT TANTHAPANICHAKOON, Ph.D.,

260 pp. ISBN 974-03-1343-4.

In the present research, the air pollutant dispersion model utilizes a 3-dimensional generalized coordinate system combined with Computational Fluid Dynamics (CFD) technique to predict air pollutant dispersion over non-planar terrain. The suitability of the model is checked by comparison with the analytical solution of a transport phenomena model for flat terrain and with wind-tunnel experiments over non-planar terrain carried out by R. Ohba, et.al. (1990). The present model is more suitable for predicting air pollutant dispersion over a wide area rather than the region near a source. Compared with wind tunnel experiments, the model is more suitable to predict the downwind concentration on the front slope of a hill than its back slope and is more accurate when the terrain has less steep difference in height.

Next computer experiments are carried out to investigate the effect of five typical factors, i.e. the wind direction, wind speed, horizontal and vertical dispersion coefficients and the exponent of the power law on the predicted 45-min. average concentration of SF₆ dispersed over an isolated hill modeled after Steptoe Butte hill, Washington State. The simulation results show that the wind direction, wind speed and horizontal and vertical dispersion coefficients have significant effect on the predicted average concentration at a majority of the receptors selected. However, the exponent of the power law has a significant effect only at certain receptors.

Finally, the model is employed to predict the average PM₁₀ concentration under various wind directions, wind speeds and vertical dispersion coefficients at various receptors located in the stone processing zone in Saraburi Province. The prediction results show that a more stable atmospheric condition, as reflected in a decrease in the vertical dispersion coefficient, increases the predicted average PM₁₀ concentration at all receptors. The predicted average PM₁₀ concentration changes significantly at a majority of the receptors when the wind direction changes because of the prevalent calm wind condition ($\leq 2\text{m/s}$). In addition, the effect of the emission rate factor is investigated. It is found that the emission factor produces a proportional effect on the observed average PM₁₀ concentration.

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ACKNOWLEDGEMENT

The author wishes to express her gratitude to her thesis advisor, Professor Wiwut Tanthapanichakoon for his encouraging guidance and suggestions throughout this study. His comments and valuable suggestions not merely provide valuable knowledge but as well broaden her perspective in practical applications.

The author would like to express gratitude to Associate Professor Chirakarn Muangnapoh, and Associate Professor Tawatchai Charinpanitkul for their stimulating and worthy comments and participation as thesis committee. Furthermore, The author is much grateful to Dr. Somprasong Srichai for his valuable advise in the factorial experiment design, worthy comments and participation as thesis committee.

Thanks are due the Graduate School, Chulalongkorn University and Thailand Research Fund (Senior Research Project of Dr. Wiwut Tanthapanichkoon) for partial financial support and for research assistantship, respectively.

Thanks are due the Pollution Control Department for useful information and survey data for this study as well as Professor Yukimasa Takemoto and his colleagues for the program source code and technical advice.

Special thanks are due Assistant Professor Pinyo Meechumna and Mr. Watcharin Kaewmaneevan, research assistant of Mining & Petroleum Engineering Department, Chulalongkorn University, for useful survey data of stone-processing plants, and Ms. Nantamas Dhattavorn for her mental support.

Besides, the author wishes to express her appreciation to her colleagues in Particle Technology and Material Processing (PTMP) Laboratory for their technical assistance on computer facility as well as the helpful advice.

Last but not least, the author is beholden to her parents and siblings for their encouragement, inspiration and eternal understanding.

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NOMENCLATURE

C_{av}	= average concentration ($\mu\text{g}/\text{m}^3$)
C	= instant concentration ($\mu\text{g}/\text{m}^3$)
g	= acceleration of gravity, 9.81 m/s^2
P	= atmospheric pressure
Q	= pollutant emission rate (mass per unit time)
K_H	= horizontal dispersion coefficient (m^2/s or cm^2/s)
K_V	= vertical dispersion coefficient (m^2/s or cm^2/s)
U_0	= mean wind speed at source height (m/s or cm/s)
U	= wind in x direction (horizontal direction)
V	= wind speed in y direction (vertical upward direction)
W	= wind speed in z direction (horizontal direction)
J	= Jacobian determinant
Re	= Reynolds number (-)
Pow	= the exponent of the power law (-)
D_{AB}	= Diffusion coefficient (m^2/s or cm^2/s)
Δt	= Step size of integration, sec
g_y	= acceleration of gravity, in y direction
U	= Contravariant flow velocity component in ξ direction
V	= Contravariant flow velocity component in η direction
W	= Contravariant flow velocity component in ζ direction
h	= the hill height (m.)

Greek symbol

ξ, η, ζ	= independent variables in generalized space
ρ	= density (kg/m^3 or g/cm^3)
μ	= air viscosity (poise or $\text{g}/\text{cm} \cdot \text{s}$)
θ	= angle of wind direction, degree