

METHANE OXIDATION: A LANDFILL STORY

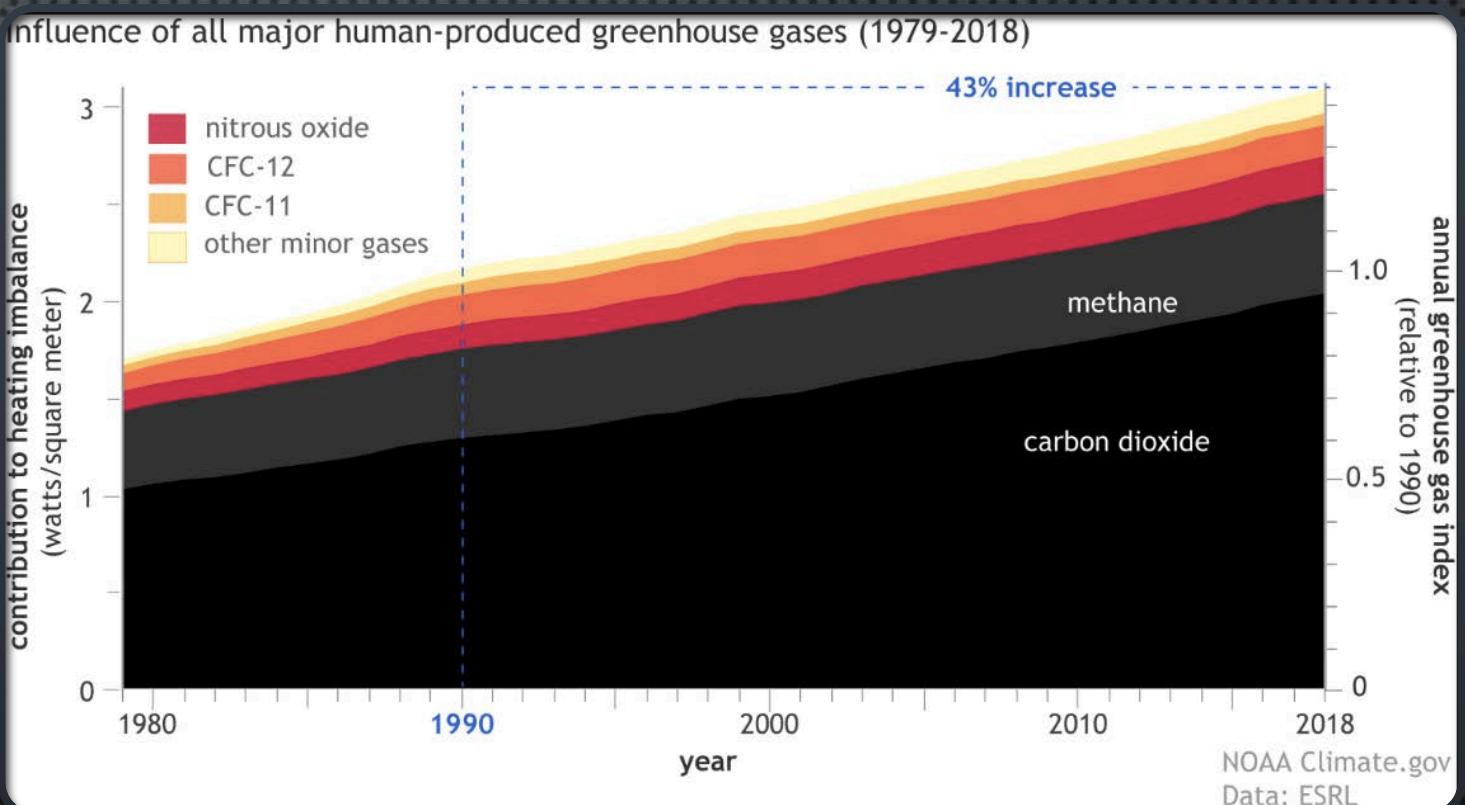


AGENDA

- OVERVIEW
- LANDFILL GAS IMPLICATIONS
- CH_4 PRODUCTION PHASES
- CH_4 OXIDATION
- EXPLOITING METHANOTROPHS
- CURRENT TECHNOLOGY AND STATE OF AFFAIRS
- FUTURE OF LANDFILLS
- CLOSING

OVERVIEW

- CH_4 HAS 25 TIMES THE RATE OF GWP THAN CO₂
- LANDFILLS ARE THE THIRD LARGEST GENERATORS OF METHANE (CH_4)
- 2.01 BILLION METRIC TONS OF MUNICIPAL SOLID WASTE (MSW) ARE PRODUCED ANNUALLY WORLDWIDE
- 3000 ACTIVE LANDFILLS IN THE U.S. ALONE
- METHANE OXIDATION CAN OCCUR, UNDER CERTAIN ENVIRONMENTAL CONDITIONS, RESULTING IN METHANE EMISSION MITIGATION.
- RESEARCHERS AND LEADING EXPERTS ARE DEVELOPING NEW TECHNOLOGY IN AN EFFORT TO EXPLOIT THE CAPABILITIES OF METHANE OXIDATION



LANDFILL GASES....SO WHAT?

- ORGANIC MATERIALS ACCOUNTS FOR 40% OF MSW IN LANDFILLS
- DURING DECOMPOSITION OF ORGANIC MSW, 90% OF CARBON IS RELEASED IN GASEOUS FORM OF CH_4 , CO_2 AND VARIOUS HYDROCARBONS
- CREATE COMPLEX PUBLIC HEALTH COMPLICATIONS IN REGARD TO THE RELEASE OF BIOAEROSOLS AND CARCINOGENIC COMPOUNDS
- ENVIRONMENTAL IMPLICATIONS REGARDING GLOBAL WARMING AND CLIMATE CHANGE
- LANDFILL CH_4 EMISSIONS, IN PARTICULAR, ACCOUNT FOR 12% OF THE TOTAL GLOBAL CH_4 CONCENTRATION EMISSIONS



HOW IS CH₄ PRODUCED?

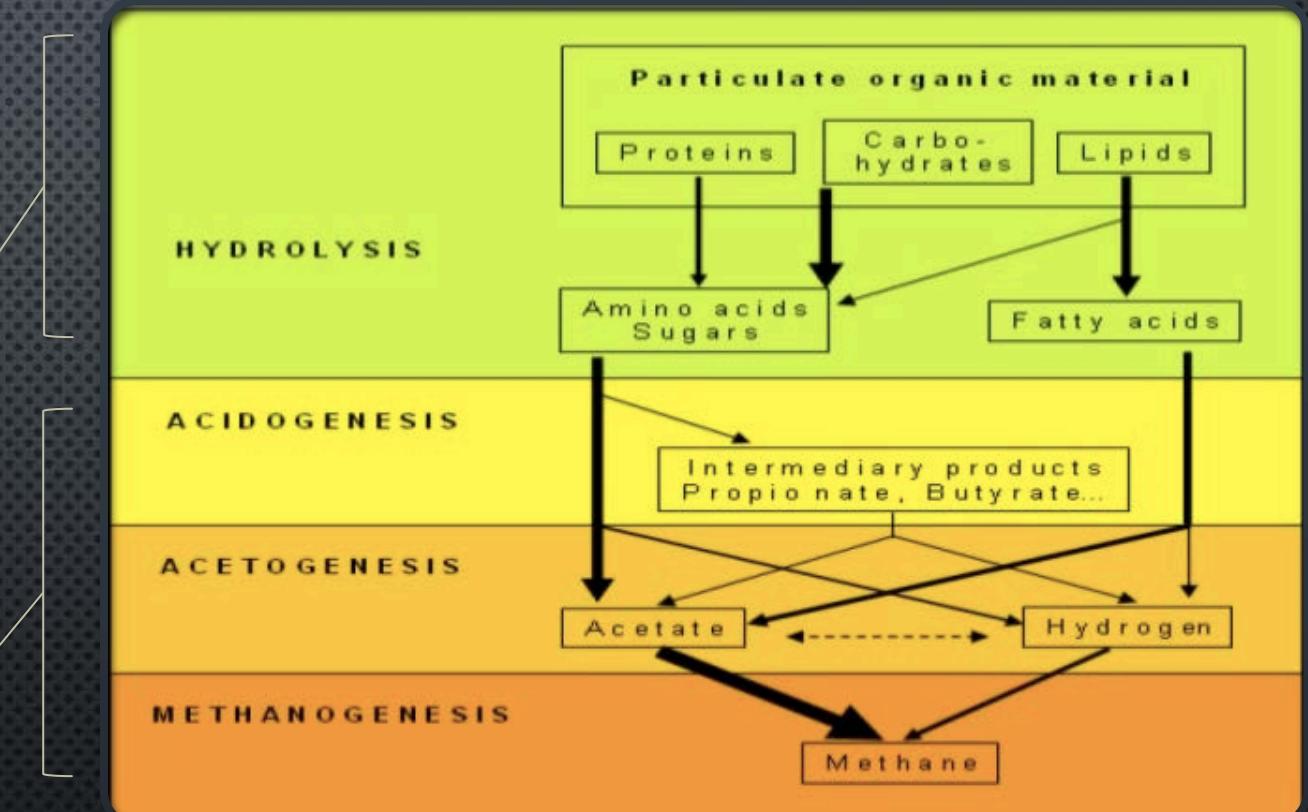
Biochemical decomposition phase: initial phase, transitional phase, acid production phase, methanogenic phase and maturation phase.

Initial phase consists of aerobic biodegradation of the introduced organic material on oxygen-rich surface levels.

Transition phase begins with the hydrolysis and biodegradation of macromolecular substances through oxygen heterotrophs.

Upon the depletion of oxygen, anaerobic conditions pave way for acid fermentation and the production of CH₄.

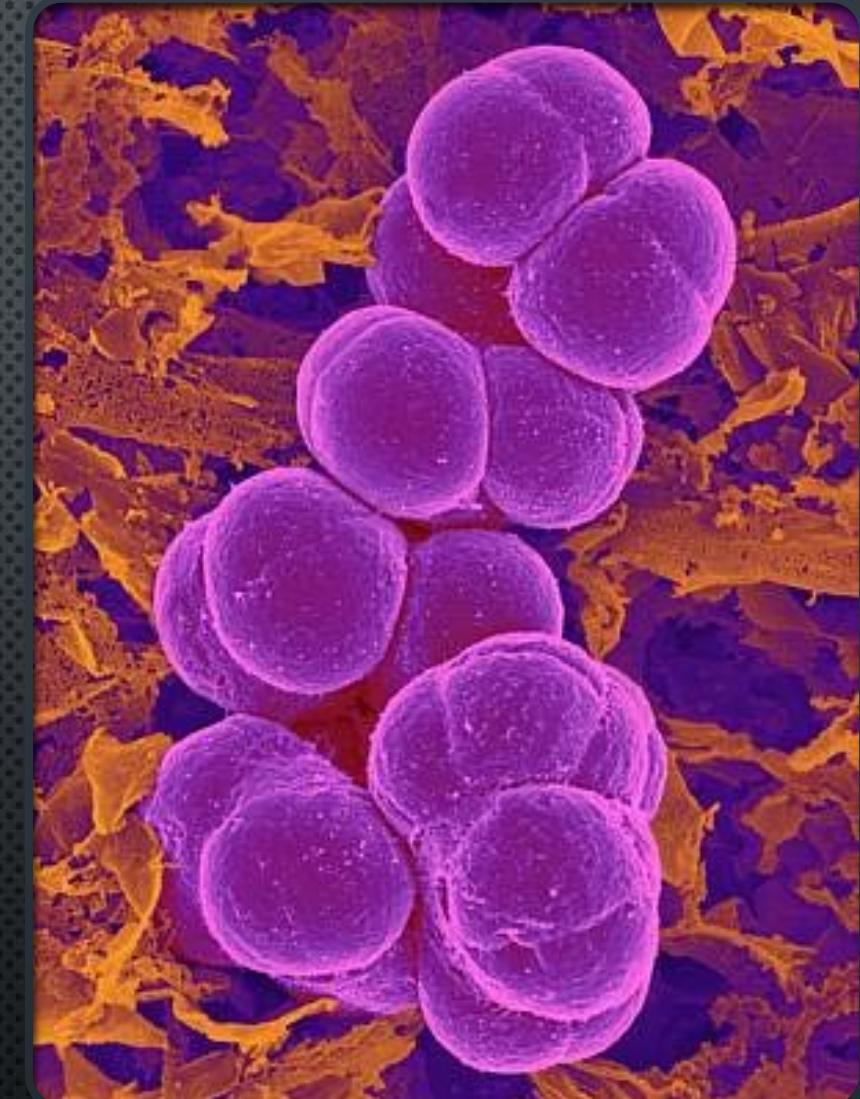
The final phase of CH₄ oxidation occurs when there is no longer organic compounds to biodegrade



(Muttu Khavi, 2013)

WHAT IS CH₄ OXIDATION?

- THE CH₄ OXIDATION PROCESS IS PERFORMED BY AEROBIC, METHANOGENIC BACTERIA THAT OXIDIZE CH₄ TO PRODUCE CO₂, H₂O, AND MICROBIAL BIOMASS ($CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ MICROBIAL BIOMASS)
- ALTHOUGH UNIQUE IN PHYSIOLOGICAL CHARACTERISTICS, METHANOTROPHS ALL RETAIN THE CH₄ MONOOXYGENASE (MMO) ENZYME.
- MMO ENZYMES ALLOW METHANOTROPHS TO OXIDIZE CH₄ FOR ENERGY YIELD.
- THERE ARE LOW-AFFINITY AND HIGH-AFFINITY METHANOTROPHS WHICH EXHIBIT VARYING LEVELS OF OXIDATION CAPACITIES. LOW AFFINITY METHANOTROPHS, EXHIBITING HIGH OXIDATION CAPACITIES, ARE PREVALENT IN LANDFILLS.



Dennis Kunkel Microscopy/science Photo Library

EXPLOITING METHANOTROPHS

The process of methane oxidation is highly sensitive to inter-dependent environmental factors such as soil texture, organic content, moisture content, temperature, pH and the availability of O₂ and CH₄ concentrations.



Soil texture controls Ch₄ emissions and oxidation rates dependent upon the porosity of the soil texture.

optimal growth: porous



Presence of soil moisture and organic content symbiotically work together to increase oxidation rates.

optimal growth: 20-35%



Inter-dependency between soil moisture content and temperature are critical in controlling oxidation capacity

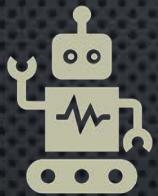
optimal growth: 20-30 C



pH of soil affects the growth of methanotrophs, acidity can be detrimental to growth

optimal growth: 5-7.5 pH

CURRENT TECHNOLOGY



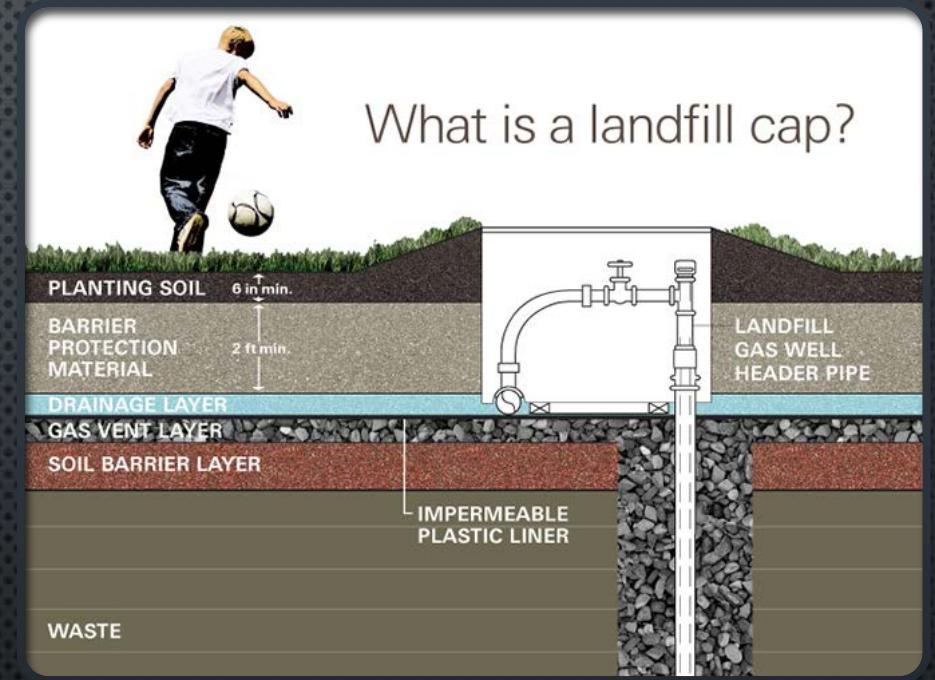
Bioreactor Systems:

Low-pressure air (aerobic) is injected into landfills along with circulation of leachate to speed biodegradation and maximize oxidation while minimizing LFG emission through a gas-extraction system



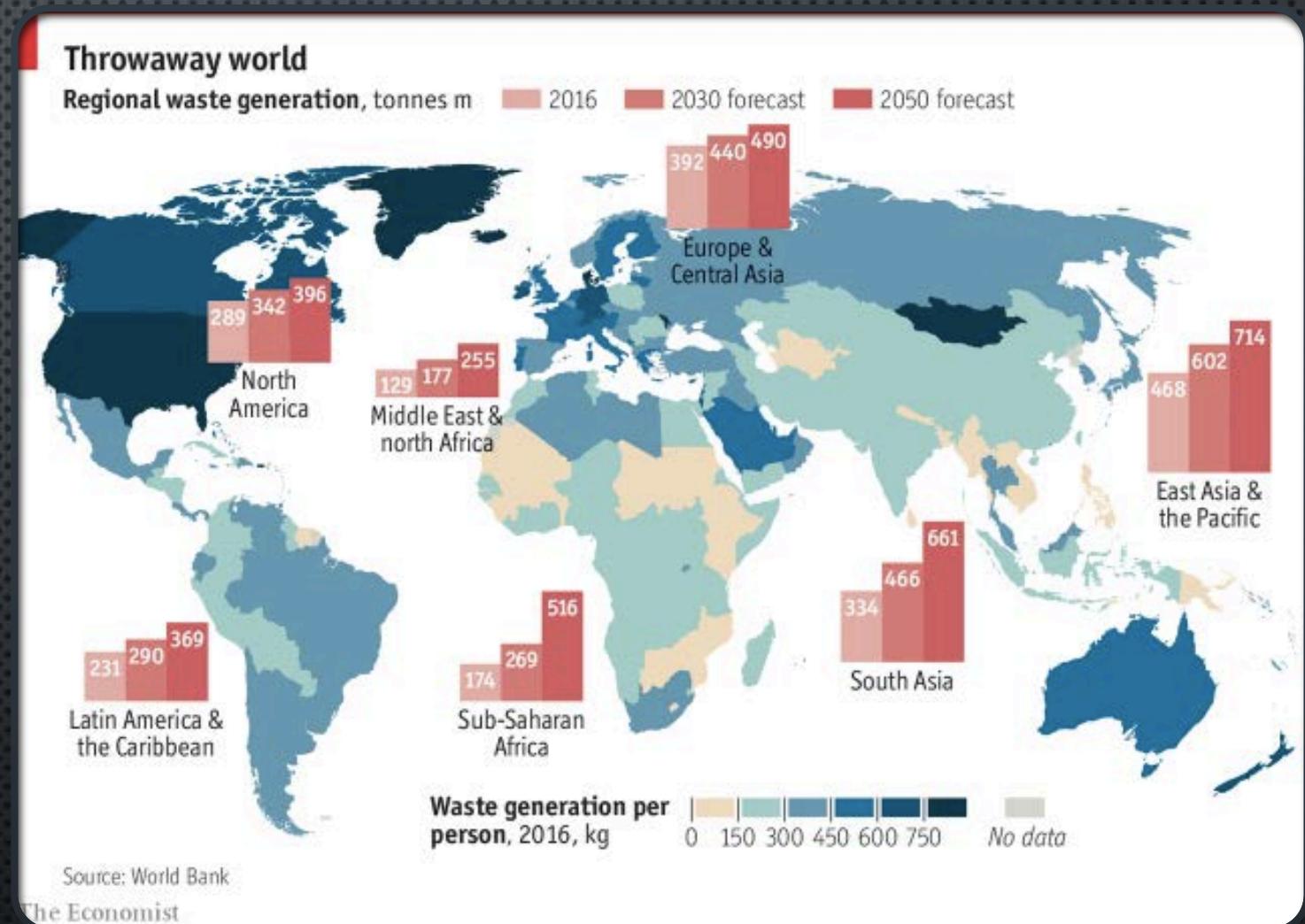
Cover Systems:

A layer of porous soil is spread over the landfill site to enhance methane oxidation by maintaining water soil balance and allowing for O₂ permeability



CURRENT STATE OF AFFAIRS

- LOWER-INCOME COUNTRIES GENERALLY RELY ON OPEN DUMPING; 93 PERCENT OF WASTE IS DUMPED IN LOW-INCOME COUNTRIES AND ONLY 2 PERCENT IN HIGH-INCOME COUNTRIES
- THREE REGIONS OPENLY DUMP MORE THAN HALF OF THEIR WASTE—THE MIDDLE EAST AND NORTH AFRICA, SUB-SAHARAN AFRICA, AND SOUTH ASIA
- UPPER-MIDDLE-INCOME COUNTRIES HAVE THE HIGHEST PERCENTAGE OF WASTE IN LANDFILLS, AT 54 PERCENT. THIS RATE DECREASES IN HIGH-INCOME COUNTRIES TO 39 PERCENT, WITH DIVERSION OF 36 PERCENT OF WASTE TO RECYCLING AND COMPOSTING



FUTURE OF LANDFILLS



WASTE MITIGATION
STRATEGIES



BIOGAS FUEL



LANDFILL MINING

QUESTIONS?