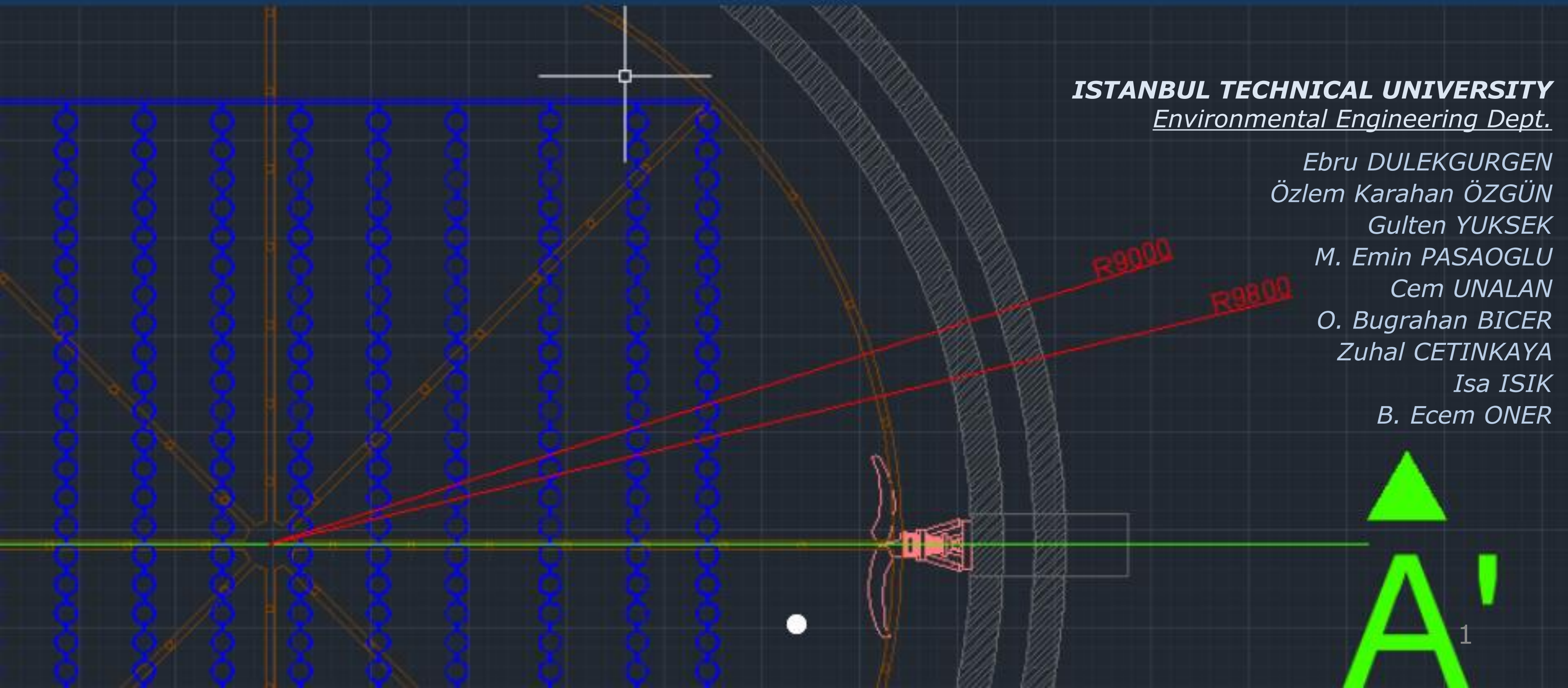
A Final Touch for the Environmental Engineering Students at the Onset of their Profession: Senior-Year Graduation Design Project, 2014-2015

Feasibility Study for and Design of a Biological Wastewater Treatment Plant for Duzce Province- Marmara Region, Turkey – ARITIYOR ENvirCo.

ICL2015 / Int. Conf. on Interactive Collaborative Learning and Engineering Pedagogy, Firenze-ITALY / 21.09.2015

The Team / Company **About the Project** **Outcomes**



ISTANBUL TECHNICAL UNIVERSITY
Environmental Engineering Dept.

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ITU / EEUP

ISTANBUL TECHNICAL UNIVERSITY (ITU)

- Founded in **1773 → first engineering academy** of the country
- Among **top-ranked public universities** in TR
- **> 25,000 undergrad students**
- emphasis on ensuring the **educational quality** and **continuous improvement** of the education
- **23 engineering undergrad programs → accredited by ABET EAC** (Accreditation Board for Engineering and Technology, Engineering Accreditation Commission)

Environmental Engineering Undergraduate Program (EEUP)

ITU-EEUP-GDP

ITU - Environ Engr Undergrad Curriculum

- **senior-year students** → ***«today's students, tomorrows' colleagues»***
- **equip them** with engr, sci & technol tools useful **in professional life**
- **contribute** to the **public** meaningfully and efficiently,
- serve for a **sustainable society resilient** enough to face, combat, and live thru the inevitable and fast **changes** of the modern times

Help students

- develop **self-learning** strategies,
- engage in **active learning**,
- enhance their **problem-solving** abilities,
- foster development of **critical thinking** skills & **decision-making** abilities,
- promote **collaborative/cooperative learning**
- sharpen **communication skills** through short- or long-term **team works** focused on **REAL-LIFE PROBLEMS**

Problem-Based Learning (PBL)

- one of the **anchors** of effective engineering education and of significance in design and content of ITU-EEUP
- several **compulsory courses** (junior/senior years) → designed & taught mainly w/a specific focus on PBL → e.g. **Graduation Design Project (GDP)**

METHODOLOGY – *Main Line*

Graduation Design Project (GDP)

- **Compulsory** → offered in both semesters at the **senior-year**
- **Student teams** → 4-5 students/team
- **Assignment** (18-19 weeks) → **design an environ engr system** to provide **solutions** to the **real-world environ problems** of selected regions in Turkey
- **Weekly meetings:** Student Team + 2 Profs + 2 TAs → Presentation of results
- **Weekly seminars:** invited experts from professional life

  → *Mostly: design of a WWTP (incl. sewer system, wastewater treament facility, treatment sludge handling & management, etc.]*

Project management work packages:

- overall framework,
- prep work and info collection regarding the project area:
  - population, demography, current infrastructure & public services, environ impacts, etc.
  - technical site-visits, meetings with local authorities,
- conceptual design,
- comparative evaluation of process/system alternatives,
- detailed process-, hydraulic-, and architectural-design and piping,
- instrument selection and P&I,
- brief risk assessment,
- financial analyses,
- project management,
- feasibility report,
- technical drawings,
- final project report
- defense in front of a jury and audience

NEW entries introduced 2014-2015 Spring

WHAT's NEW in ABET?

Changes in Program Criteria for Environ Engr

ABET EAC 2010-2011 Prog Criteria

1. Curriculum

The ***program*** must ***demonstrate the graduates have***:

- ***proficiency in*** mathematics through differential equations, probability and statistics, calculus-based physics, ~~*general*~~ ***chemistry***, an earth science, ~~e.g., geology, meteorology, soil science, relevant to the program of study~~, a biological science, ~~e.g., microbiology, aquatic biology, toxicology, relevant to the program of study~~, and fluid mechanics ~~relevant to the program of study~~;
- ***introductory level knowledge of environmental issues associated with*** air, ***land***, and water systems ~~and associated environmental health impacts~~;
- ~~an ability to~~ conduct laboratory experiments and to ~~critically~~ analyze and ***interpret data*** in more than one major environmental engineering focus areas, e.g., air, water, land, environmental health;
- ~~an ability to~~ ***perform engineering design by means of design experiences integrated throughout the professional component of the curriculum***;
- ***proficiency in*** advanced principles and practice relevant to the program objectives;
- understanding of concepts of professional practice and the roles and responsibilities of public institutions and private organizations pertaining to ***environmental*** ~~***engineering***~~.

ABET EAC 2015-2016 Prog Criteria

1. Curriculum

The **curriculum** must **prepare graduates to**

- **apply knowledge** of mathematics through differential equations, probability and statistics, calculus-based physics, **chemistry (including stoichiometry, equilibrium, and kinetics)**, an earth science, a biological science, and fluid mechanics.

The curriculum must prepare graduates to

- **formulate material and energy balances**, and **analyze the fate and transport of substances in and between** air, water, and **soil** phases;
- conduct laboratory experiments, and analyze and **interpret the resulting data** in more than one major environmental engineering focus area, e.g., air, water, land, environmental health;
- **design environmental engineering systems that include considerations of risk, uncertainty, sustainability, life-cycle principles, and environmental impacts**; and
- **apply** advanced principles and practice relevant to the program objectives.

The curriculum must prepare graduates

- **to understand concepts of professional practice, project management, and the roles and responsibilities of public institutions and private organizations pertaining to environmental policy and regulations.**

METHODOLOGY – *What's New in GDP?*

NEW Themes

Environmental Management Considerations (ABET EAC,15-16):
risk, uncertainty, sustainability, life-cycle principles, and environmental impacts
Advanced Principles & Practice

NEW Teaching Strategies

Mentors
(instead of instructors)
Peer Reviewer

NEW Technol

Advanced Principles & Practice
An Innovative Treatment Technol as main WWT unit

GDP

Info and data collection
Technical site-visit
Meeting w/ local authorities
Conceptual design
Solution alternatives
Detailed design and technical drawings (process, hyrdaulics, architecture, P&I)
Risk assessmnet
Financial analysis
Feasibility
Final report
Defense

METHODOLOGY – *What's New?*

Team Structure and Project Management:

- **Senior-year students** (4) → members of the GDP-team *[& partners of the virtual project management company (ARITIYOR ENvirCo.)]*
- **Peer reviewer** (1) jr engineer (grad of Class2014) joined the team → senior reviewer of the team *[& consultant of the virtual Co.]*
- **Mentors** (2 Profs. + 2 TAs) → instead of conventional "instructors" → mentors of the team *[& external senior & junior consultants of the virCo.]*

METHODOLOGY – *What's New?*

New themes outlined by ABET EAC (2015-2016) incorporated:

- **risk assessment** (RA)
- **uncertainty**
- **sustainability**
- life cycle principles
- project management, and **further**
- risk assessment-management (RAM)
- **life-cycle-assessment (LCA)**
- **resilience** analysis

Technology selection for designed BioWWTP:

- Innovative **Aerobic Granular Activated Sludge (AerGAS) Technology** *–Greenfield parallel extension-*

http://www.royalhaskoningdhv.com/en-gb/nereda

OUTCOMES – *Uncertainity*

Highlights of Uncertainty Considerations:

Common and precautionary practice:

- **safety factors/coefficients** in process calculations and WWTP design
- **Ensures** reaching the set **effluent standards** even under conditions of **continuously fluctuating** influent overflow rates and pollution loads

Avoid inflated safety factors

- May result in **overdesign!**
- Will **jeopardize feasibility** of the project!

Applied design approach for each treatment unit:

- **basic, simple,** yet **flexible** and ensuring the effluent standards
- **Final Check!** → all calculation / designs **strictly checked against design-, average-,** and **peak- flow rates**

OUTCOMES – *Risk Assessment*

Highlights of RAM

Conventional -Risk identification, assessment, management aspects:

- occupational health and safety
- legal responsibilities
- financial threats

✓ **Integrated RA + perspective of real-world experiences**

- most frequent risk factors identified
- data collection and analysis → occupational accidents occurred in TR (past 5 years) in operating WWTPs

✓ **Emergency Action Plan (EAP)**

- specific high-risk units & high-risk maintenance activities of the designed treatment facility
- precautionary measures & responses in case of possible high risks
- precautionary steps outlined and imposed by the related state authorities and controlling bodies, as well as the most up-to-date national legislation → closely followed

✓ **Financial risk analyses**

- Cost analyses (full treatment train)→ capital, operational, maintenance costs, tariff values
- ***Result*** → innovative AerGAS WWTP → **more feasible** and **less prone to financial risks** compared to the conventional alternative

NEW -Risk identification, assessment, management aspects for AerGAS Technol:

- first in Turkey
- risks of implementing the innovative AerGAS Technol as the treatment alternative
- ***Result*** → **main risks** with **mid-to-high impact** were mostly **due** to the **innovative nature** of the AerGAS technology [Table-I]

OUTCOMES – *Risk Assessment*

NEW-Additional Risk Assessment

Specific for implementation of Innovative AerGAS Technology

(RA in addition to the Emergency Action Plans)

TABLE I. RISK ASSESSMENT FOR INNOVATIVE AEROBIC GRANULAR ACTIVATED SLUDGE TECHNOLOGY

	Risks[a]	Scoring[b]			
		0	*1*	*2*	*3*
A	*Success/failure of this new technology and effect on acceptance of innovative technologies in general*				
1.	Failure of a new technology may adversely affect innovation in general				X
2.	Stricter effluent requirements complicate the choice for innovative technology		X		
B	*Economical risks*				
3.	Capital costs due to construction and implementation of this innovative system might exceed acceptable boundaries			X	
4.	Local/national market perspectives may be limited due to preliminary difficulties in implementation of innovative technologies				X
5.	International market interest, demand, and profit return might be too low	X			
C	*Sensitivity of the treatment process*				
6.	The system may not cope with influent fluctuations (volume, composition, temperature)	X			
7.	Controllability of formation, maintenance, structural/functional stability of AerGAS		X		
8.	Operational instability due to lack of self-regulation		X		
9.	Expensive back-up mechanisms needed in case of stopping the process due to lack of robustness might increase costs			X	
D	*Lack of similar full-scale systems and possible problems in up-scaling the present lab- and pilot-scale applications*				
10.	Although couple of lab-scale [12-15] and one pilot-scale [16] AerGAS studies have been executed in Turkey, certain factors, and thus results of those studies might fail to be representative			X	
11.	No similar full-scale systems are present in Turkey as of today, and certain factors can only be assessed in full-scale			X	
E	*Meeting discharge requirements and such*				
12.	The process fails to meet the effluent discharge standards		X		
13.	The system fails to meet excess sludge handling requirements	X			
F	*Other Risks*				
14.	Difficulties in sludge processing compared to handling of conventional AS		X		
15.	Difficulties in allocating adequately qualified and competent operators, etc.				X
16.	Process calculations and technical design, done for the first time in Turkey, failing to represent real-world conditions		X		

[a] Entries in the table were adapted (with some modifications) from [11]

[b] Risk-impact scoring: (0) Irrelevant; (1) Low; (2) Medium; (3) High

OUTCOMES – *Sustainability*

Highlights of Sustainability:

Economic Aspects

- capital-, operational-, maintenance- costs including:
- land requirement, number & capacity of selected mechanical equipment,
- choice of treatment technol

Innovative AerGAS WWT Technology

- significant energy savings and lower operational costs:
- **24% less energy** than conventional A2/O WWTP
- **26% lower overall operational costs** than conventional A2/O WWTP

Land requirement

- Lower land requirement:
- **60% smaller land** than that needed for conventional system
  - excellently settling compact structure of granular sludge and SBR config →
  - reactors with *smaller footprints*,
  - *no* separate *secondary clarifiers*
  - unused area → recreational activities
  - lessen social resistance and negative response to the treatment plant
  - mitigate presumed negative impacts on the local community

CO_2 emissions

- Reduced energy consumption → **less indirect atm CO_2 emissions**
- pursuing **public health** aspects and further contributing to sustainability

OUTCOMES – *LCA*

Highlights of Life Cycle Assessment (LCA):

- evaluate ***total environ impact*** of treatment processes
- understand how to ***avoid shifting environ impacts*** from one place to another
- used framework/standards → ***ISO 14040:2006 standard***

1. Defining scope and goal:

- select **proper** and **representative** **system boundary**
- ***Result*** → exclude impacts due to construction activities and focus on **30-years operational period**

2. Inventory analysis:

- plentiful data available → process calculations, system design equipment selection were carried out by Team-7 (data : **not** the limiting factor)
- required to check reliability of data vs actual indicators from similar plants →
- Data collection & comparison → energy requirement data from currently operating full-scale AerGAS WWTPs
- ***Result*** → flowchart incl. **inputs /outputs** in & out of **each unit** of the designed WWTP (**Fig.1**)

3. Impact analysis:

- determine **impact categories** before to calculate & assess important impact factor
- ***Result*** → focus on "**Global Warming Potential (GWP)**" → simple yet representative major impact category (*publically accessible tools & software*)

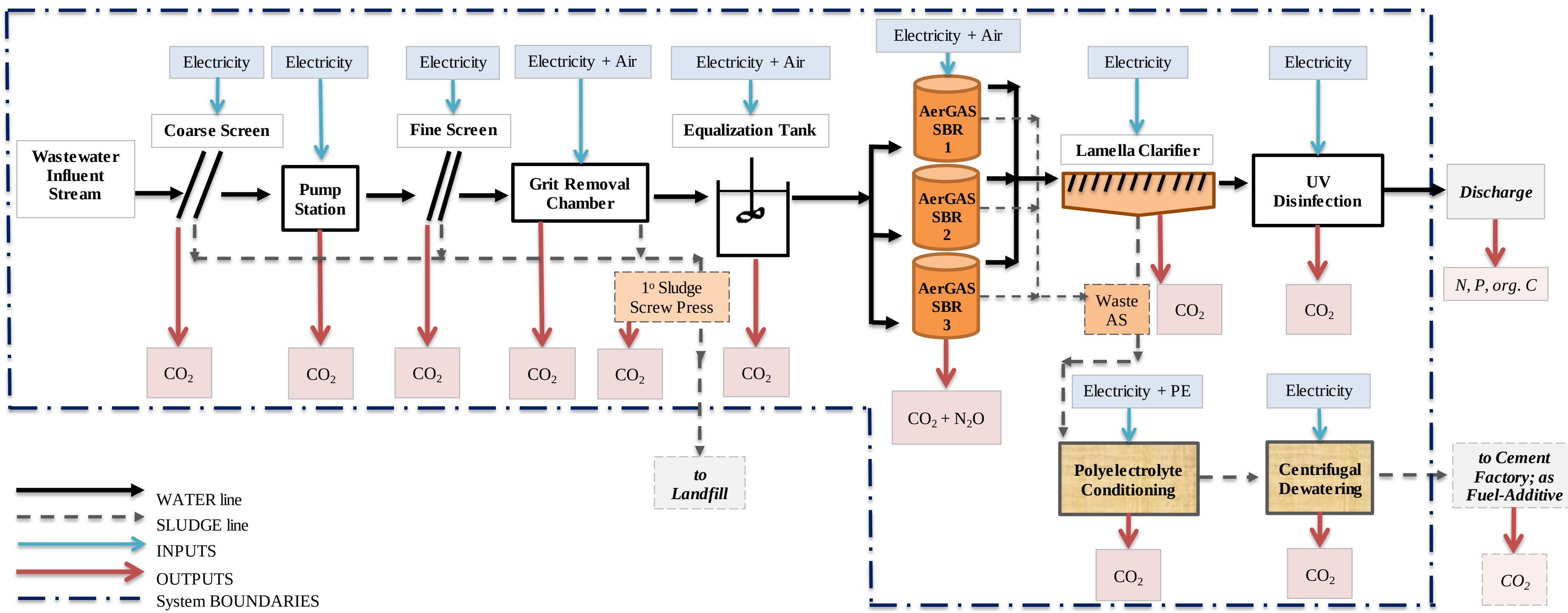
4. Interpretation (estimating GWP of the WWTP):

- **N, P, organic-C emissions** to aquatic environ (discharge to Melen Creek, Turkey)
- **indirect atmospheric inorg. C & N emissions** (CO_2 equivalence) from the designed treatment facility
- ***AerGAS WWTP → lower energy consumption of → lower CO_2 emissions***
- Approx. 50% CO_2 emissions (7% from N_2O) → due to **pumping**
- Main biological unit → lesser share in the GWP of the system

OUTCOMES – *LCA/inventory analysis*

Life cycle assessment (LCA)

Inventory analysis for the AerGAS-based BioWWTP designed for Duzce Province- Marmara Region, Turkey



OUTCOMES

Highlights of Resilience Analyses:

- Interrelations between resiliency & sustainability → sustainability of civil structures is heavily dependent on resiliency of operation;
- basic but important precautionary actions planned mainly considering the threats due to **earthquakes** and **floods**.
- *guidelines* → by Environmental Protection Agency-EPA
- *Process* → 6 basic prevention aspects determined
- *Example* → protecting sensitive equipment from floods by building barriers and blocks, etc.

✓ **RESULTS:**

- most important element → **emergency back-up generators** and back-up **reserves**: crucial in terms of independent operation during times of crisis and natural disaster.
- critical aspects of resiliency → **Interdependency**
- included in assessment and planning → ***dependencies to other infrastructure systems***:
- Designed WWTP would be compatible with earthquakes or floods, YET
- recovery period would heavily depend on the conditions of other infrastructures (i.e., *transportation corridors, energy infrastructure, supply chains*, etc.).

CONCLUSIONS / *Student Entries - I*

Inclusion of **new environ management considerations** in the GDP

New approaches of handling **problem/design-based** education

significantly **broadened the perspective** of **our senior-year students**, as obvious from ***their comments*** on *risk concepts, risk assessment-management, uncertainty, sustainability, life-cycle-assessment, and resilience*:

1. **Risk management** → **inevitable** for **sustainable** engineering systems. Identification, assessment, evaluation of natural and/or man-made risks & hazards must be among the **priorities** of a sustainable engineering perspective.
2. **Sustainability**: "*meeting todays' demands without compromising the needs of next generations*" → not only an issue of **management of energy resources**, but also should be the motto for **existence & coherence of civil works/services** contributing to the prosperity and resilience of the public, and to preserve, protect, remediate environment.
3. Putting **every step** of this project into the **"sustainability" perspective** → not only **positively influenced** the entire **design-** and **decision making**- phases, but also enabled **us** to get one step **closer to today's real-world standards** in environ problem solving.
4. **Preparedness** embodied in "risk analyses & management" → will ensure that projects and services **meet real-world expectations & needs** → will also provide the chance to establish a **sustainable operational practice**.

CONCLUSIONS / *Student Entries - II*

5. **Risk management** should be included in **environ edu** in a **cause-and-effect** context. **Multidisciplinary approaches** should be used in RA.
6. **Taking risks** does **not** always mean **bravery**; rather it might be a sign of illiteracy. Hence, **backup plans** are **always necessary**.
7. **Risk management** should be done by an **engineering approach** based on scientific facts, technical analyses & calculations **beyond assumptions** and **probabilities**.
8. **Understanding** the **principles** and **purpose** of “life-cycle assessment (**LCA**)” was one of the **most important gains** from this project → a **valuable tool** to be **used frequently** and **effectively** in Environmental Engineering **profession**
9. **LCA** is a powerful tool for **understanding material** and **energy cycles**. Besides, it clearly demonstrates that **transferring pollution** from one location/medium to another does **not** provide a **sustainable** and **integrated** Environmental Engineering solution.
10. **Resilience** was an **important new consideration** in environ management → **broadened our vision** by requiring us to consider the **interdependencies** of the designed treatment plant to other civil infrastructures in case of natural disasters and such.
11. Consideration and assessment of **resiliency** is prone to help **create flexible** and **robust solutions** in all engineering disciplines.

ACKNOWLEDGMENT

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THANK YOU

for

YOUR ATTENTION


Week-2: Site-visit
Week-13
Week-17
ÇEVKO
Week-19: DEFENSE
Week-2: Municipality
DEFENSE
DÜZCE - CUMAYERİ ve GÜMÜŞOVA İLÇELERİ
(İLERİ) BİYOLOJİK ATIKSU ARITMA TESİSİ
PROJESİ
Week-12
Week-14
BEST Project Award
Büşra Ecem Öner
Osman Buğrahan Biçer
Zuhal Çetinkaya
Week-15
İTÜ
İNŞAAT FAKÜLTESİ
Week-18: Submission
GRADUATION'15