Building a Risk Assessment at Naco Elementary School

A combined effort between Naco Elementary School, Cochise County Health and Social Services, and the University of Arizona

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EXECUTIVE SUMMARY

The following report seeks to describe the work that was accomplished during the time of the CLIMAS Environment and Society Graduate Fellows Program.

Importance of research project

Transboundary untreated wastewater flows have affected Ambos Nacos (Naco, Arizona, U.S.A., and Naco, Sonora, Mexico) since the mid-1980s. During summer monsoon and winter rains, elevated storm water flows create an overstrain on wastewater collection and treatment systems in Naco, Sonora which results in Sanitary Sewer Overflows (SSOs) flowing northward due to the natural topography of the land.

Wastewater pollution is a major issue of concern worldwide because of the presence of pathogens and infectious microorganisms in polluted waters. Exposure to faecally contaminated water or soil poses a risk to public health, especially in immunocompromised groups such as pregnant women, the elderly, and children (Katukiza et al., 2013). The nature of sewage systems and their effluents should be regarded as important locations for monitoring and human enteric virus transmission. The US-Mexico Border 2020 Health Promotion Initiative identifies environmental health factors such as access to water and sewer services, as one of the main causes for infectious disease problems (US-Mexico Border Health Commission, 2015).

Our research objectives are: a) build capacity by co-implementing a water and soil sampling plan; b) assess potential health risks to Naco Elementary students; c) share results with the Naco community and produce educational materials to promote a larger awareness around SSOs.

Key partners & target audience

Key Partners

- Cochise Health and Social Services (CHSS) is the county-level agency responsible for ensuring a safe and healthy environment for Cochise County residents. CHSS declared a State of Emergency in 2018 due to chronic and high volume of SSOs affecting residential and non-residential areas.
- Naco Elementary School is the only school in Naco, Arizona. Its families reside in Ambos Nacos. Students, parents, teachers, and administrative staff have contributed to this project.

Target Audience

- Naco community residents- in particular, members of Naco Elementary School.
- Arizona Department of Environmental Quality Office of Border and Environmental Protection (ADEQ OBEP) and the Arizona Department of Health Services Office of Border Health (ADHS OBEH).
- Other researchers and professionals working in environmental and public health projects.

Project design & methods

This project follows the Quantitative Microbial Risk Assessment (QMRA) framework. It is a widely used risk assessment tool which quantifies the potential risk to human health of a pathogen or contaminant of interest. QMRA is composed of four major steps:

a) problem formulation (hazard identification)
b) exposure assessment
c) health effects assessment (dose-response assessment)
d) risk characterization

This project is unique in that it seeks to incorporate the local knowledge and expertise of all parties involved, in order to collaboratively build a site-specific risk assessment.

Outputs & outcomes

- Environmental monitoring plan was co-designed by CHSS and the University of Arizona Environmental Science (UA ENVS).
- Soil samples were collected in February, April, and July 2019.
- CHSS Environmental Health Specialist was trained by UA ENVS on soil and water sample collection and storage, and field testing for total coliforms and *E. coli* following a modified method from Aquagenx *E. coli* and total coliforms water quality test kit.
- Three survey versions were designed targeting parents (surveys available in English and Spanish), teachers, and the school's principal. Questions address students' hand-to-mouth behavior, duration (time) and outside location where students play/congregate, risk perception and risk communication.

Lessons learned

- Use-inspired and engaged research requires large inputs of time and effort by all involved parties to develop trust, confidence and direction. All while accounting for varying internal priorities, structural changes, and schedules.
- Developing relationships within various members of an organization helps create a more sustainable and robust relationship with such organization.
- Effective environmental and public health projects consider me perspectives in the social and political domains.

Future work

- Collect soil and water samples after a heavy rain event, and complete lab analysis of such samples to obtain contamination concentrations.
- Finalize survey-data analysis
- Complete Risk Characterization portion.
- Produce educational materials along with CHSS. Hold a data-sharing event to report back results to Naco community and distribute produced materials.
- Hold a report-back event at Naco Wellness Initiative (Naco, Sonora).

INTRODUCTION

Arizona and Sonora share a 362-mile international border which bring with it a variety of environmental and public health challenges that require binational cooperation. Naco, Arizona is a small rural town just south of Bisbee and is immediately adjacent to its sister border city Naco, Sonora, Mexico. Collectively, the towns are referred to as Ambos Nacos (Both Nacos). Naco, Arizona is an unincorporated community of approximately 1,000 residents in Cochise County. It has one public school of 270 students, where 150 of them come from Naco, Sonora. The school is directly across the Naco Point of Entry where many families cross by foot.

Transboundary untreated wastewater flows have affected Ambos Naco since the mid-1980s. During summer monsoon and winter rains, elevated storm water flows create an overstrain on wastewater collection and treatment systems in Naco, Sonora which results in Sanitary Sewer Overflows (SSOs). Residents in Ambos Naco, as well as Arizona government agencies in environmental quality and public health, and their Sonora counterparts, have expressed concern over contaminant presence in SSOs. However, no conclusive efforts have related SSOs to potential impacts to human health.

This report describes the progress achieved during the CLIMAS fellowship which helped support collaborative community research between Cochise Health and Social Services (CHSS), Naco Elementary, and the University of Arizona Department of Environmental Science (UA ENVS). This work conforms part of my thesis for completion of a Master's in Environmental Science.

Importance of work and objectives

Wastewater pollution is a major issue of concern worldwide because of the presence of pathogens and infectious microorganisms in polluted waters. A large presence of human-specific enteric viruses in untreated wastewater can cause vomiting, diarrhea, nausea, cramping and abdominal pain (Ahmed et al., 2018). Exposure to faecally contaminated water or soil poses a risk to public health, especially in immunocompromised groups such as pregnant women, the elderly, and children (Katukiza et al., 2013). The nature of sewage systems and their effluents should be regarded as important locations for monitoring and human enteric virus transmission.

On September 9th, 2018 Naco, Arizona, received untreated effluent flowing in from Mexico at the Naco Point of Entry. The effluent flowed north parallel to Naco Elementary and made its way into the arroyo where it followed its natural course to the West of Naco towards the San Pedro River. Discharge continued up to 250,000 gallons per day through October 7th, 2018. Cochise Health and Social Services (CHSS) Environmental Health team responded to the raw sewage flow by collecting direct grab samples and sending them to the Arizona Department Environmental Quality (ADEQ) laboratories. All seven samples tested positive for Coliform and *E. coli* bacteria. A State of Emergency was declared. Obtained funds were used to provide immunization clinics to Naco residents. Furthermore, soil berms were built to contain the pooled water and chlorine tablets were added for disinfection. The Director of Cochise Health and Social Services expressed concern over the limited response from State agencies and her office's restricted resources (only one full-time designated Environmental Health staff member), which led her to seek outside assistance.

U.S. environmental policy largely follows a cooperative federalism framework which calls for shared responsibility among the federal, state, and local government to solve problems. Recent environmental policy has shifted a greater emphasis towards the state and local governments' role as environmental implementers and enforcers (Austin, 2004; Konisky & Woods, 2018). However, a decentralization of decision-making pose challenges to local governments that might not possess the technical or financial resources to address environmental problems. Thus, partnerships present valuable opportunities to find solutions to complex problems where resources are scarce or where low level of confidence in government institutions exists (Austin, 2004). A community-university partnership between CHSS and UA ENVS initiated in October 2018 to address the SSOs in Naco, Arizona. Our objectives include: a) build capacity by co-implementing a water and soil sampling plan, b) assessing health and environmental risks, and c) share results with the Naco community and produce educational materials that promote a larger awareness around SSOs.

Stakeholders

Originally, the partnership was primarily between CHSS and UA ENVS, however, as conversations progressed, we identified an urgent need to address the SSO which flowed by the school wash- only a few hundred feet from Naco Elementary School. Thus, building a relationship with the school was fundamental.

During our initial meeting with the school's principal at the time, he walked us around the school's premises and described his vision for the school. Where garden beds had once produced, these were now harshly deteriorated, and the land was unused. Efforts to rebuild the school garden and construct a nature pathway along with a kiosk by the track, had been halted due to concerns of possible microbial contamination due to SSOs.

Considering Naco Elementary's needs, our objective was readjusted to focus on assessing health risks specifically to students of Naco Elementary. The results of the assessment could further be used to inform the school's decision in building the school garden. This information was presented at the School Board meeting where they motioned to approve their collaboration and allow us to take samples within school premises. The administrative staff, teachers, parents, and students have all contributed to this project. All results will be shared with the Naco Elementary School community and interested community members.

A significant portion of Naco Elementary students (approximately 55%) reside in Naco, Sonora. Some of these families do not hold the legal documentation to enter the United States. Since SSOs are also prevalent and affect Naco, Sonora, we hope to partner with the Naco Wellness Initiative to reach the families of these students. The Naco Wellness Initiative is a nonprofit which provides medical and wellness services in Ambos Nacos. Their facility in Naco, Sonora has been used to hold Skype meetings between students' teachers and their parents, and to hold workshops and events.

There has been multi-agency involvement in tackling chronic SSOs in Ambos Nacos including from the Arizona Department of Environmental Quality Office of Border and Environmental Protection (ADEQ OBEP) and the Arizona Department of Health Services Office of Border Health (ADHS OBEH). ADHS OBEH has assisted with providing vector data. ADEQ OBEP has been instrumental in working closely with Sonoran water government agencies to improve wastewater treatment infrastructure, finalizing this effort in 2019. Both agencies are aware of the CHSS-UA ENVS partnership and are therefore a target audience.

PROJECT DESIGN & METHODS

To help guide our efforts in assessing the potential health risks to Naco Elementary students from SSOs, we followed a Quantitative Microbial Risk Assessment (QMRA) framework. QMRAs are widely used risk assessment tools which quantify the potential risk to human health of a pathogen or contaminant of interest. It has tremendous values to water safety management and many other applications. The World Health Organization (WHO) specifies four components to QMRA:

a) problem formulation (hazard identification)
b) exposure assessment
c) health effects assessment (dose-response assessment)
d) risk characterization

QMRAs are used world-wide and assist regulatory agencies in achieving the United Nations' Sustainable Development Goals related to wastewater pollution, environmental health, and environmental justice (WHO, 2016).

Hazard Identification

Poor sanitation systems and wastewater have high concentrations of enteric viruses, bacteria, helminths, and protozoa (Katukiza et al., 2013). Rotavirus is a human enteric virus that is the leading cause of acute viral gastroenteritis in children worldwide (Jothikumar et al., 2008). Before the two live-virus vaccines were available, most children were infected with rotavirus before their fourth birthday in both developed and developing countries (Cook et al., 1990). Due to its low infectious dose, prevalence in children, ability to resist inactivation in the environment, resistance to disinfection, and ease of transmission between environmental samples, rotavirus was chosen as the pathogen of interest for the QMRA (Paul et al., 2013; Jothikumar et al., 2008).

Presence of total coliforms, *E. coli*, and ascaris worms were also monitored for as indicators for fecal contamination.

Exposure Assessment
I) Environmental Monitoring
A total of 58 samples were collected during the months of February, April, and July 2019. For the first sample collection event CHSS' Environmental Health Specialist accompanied the UA ENVS team and collectively decided which areas were important to sample from. Sites that were sampled included within the proposed school garden site and along the nature path, inside the school's baseball field, along the school wash, and in the areas where wastewater has historically pooled.

Soil samples were taken from the top 5 inches of soil using single-use sterile tongue depressors and placed inside Ziplock bags. These were transported in an ice cooler and taken to the UA Water & Energy Sustainable Technology (WEST) Center. Soil extractions were prepared by mixing 10g of soil in 100 grams of 0.85% NaCl solution and mixed in an open-air shaker for 5 minutes. Volumes measuring 1mL (0.1g assay equivalent) were taken from each soil extraction, brought up to 100 mL using sterile water, and then assayed following the Colilert method (SM 9223B) to test for total coliforms and *E. coli* quantification. 2mL of soil extraction was saved in cryovials and frozen at -80°C. Unused soil samples were stored at -20°C.

Figure 1. Map of Naco Elementary School in Naco, AZ. Sampling site locations and contaminated areas are highlighted.

Rotavirus concentration in soil will be determined through quantification of the Pepper Mild Mottle virus (PMMoV) via quantitative PCR (qPCR). PMMoV is a pepper plant pathogen that causes fruit malformation and leaf mosaic. Processed pepper products such as dry spices, curry, and sauces commonly contain PMMoV; sauces can contain up to 108.8 PMMoV targets per mL. The wide consumption of processed pepper products in humans' diet, manifests in the presence of PMMoV in human feces (Symonds et al., 2018). The virions of PMMoV are rod-shaped and "extremely stable and have demonstrated to retain their infectivity for plants after passage through the human gut" (Rosario et al., 2009). Unlike enteric viruses, the presence of PMMoV in fecal contamination is not dependent on an infected population, thus it could present a better marker for fecal contamination than more traditional methods such as fecal indicator bacteria. Furthermore, bacterial indicators are not directly correlated with the presence of pathogens and feces-associated viruses such as enteric viruses (Rosario et al., 2009; Symonds et al., 2018). Studies show PMMoV is an appropriate index virus for enteric viruses in waters that have been affected by fecal contamination (Symonds et al., 2018). Index surrogates are used to represent a targeted pathogen (e.g. rotavirus).

II) Routes of Exposure

Rotavirus is primarily transmitted through the fecal-oral route; infected hosts shed large number of virus particles that are easily transmitted through environmental sources and are ingested orally by another person (Paul et al., 2013). As part of their natural development, young children engage in hand-to-mouth behavior and other mouthing behaviors such as licking, sucking, and chewing, therefore, it is important to consider non-dietary soil ingestion for environments affected by pathogenic microbial contamination (Pickering et al., 2012; U.S. EPA, 2008). In our assessment we chose to focus on fecal-oral route transmission via hand-to-mouth behavior.

The U.S. EPA Child-Specific Exposure Factors Handbook reviews children's exposure data and provides recommended values for exposure factors (i.e. hand-to mouth frequencies) and confidence ratings as a source of data for exposure and risk professionals. Human behavior is difficult to quantitate and ranges widely. To produce a risk assessment specific to the Naco Elementary community, surveys were designed to provide site- and population-specific data to be used along with the values from the U.S. EPA Child-Specific Exposure Factors Handbook. Three survey versions were designed targeting parents, teachers, and the school's principal. All include questions touching on risk perception and risk communication. Further questions were asked depending on the audience.

Additional questions to teachers include:

- location and duration of time students spend outdoors
- precautions taken to avoid tracking soil into classroom
- risk perception
- observed children behavior (i.e. hand-to-mouth)

Additional questions to parents include:

- demographics

- mode of transportation to get to school
- if student walks, what are the routes they take?
- precautions taken in response to sanitary sewer overflow events

Additional questions to the school's principal include:

- historical land use of school
- school-wide actions during past SSOs

Dose-Response Assessment

Microbial contaminants will have different relationships between dose and level of adverse effect. Dose-response curves are a mathematical representation between the amount of contaminant a human is exposed to and the expected adverse effect (Maier et al., 2009; QMRAwiki, 2020). Probability of rotavirus infection will be calculated using the beta-Poisson model (α = 2.6E-01, β = 0.42) (Maier et al., 2009).

$$P = 1 - (1 + N/\beta)^{-\alpha}$$

Risk Characterization

In this component of QMRA all factors of the exposure assessment and dose-response assessment are integrated to estimate the dose and quantify the level of risk. Uncertainty lies in every factor; thus, it is an iterative process which often requires sensitivity analyses and Monte Carlo simulations. Monte Carlo simulations account for uncertainty and variability within the parameters. Below is a table of factors that will be considered. Values from peer-reviewed studies and the U.S. EPA will be used in the risk characterization. Additionally, values from the surveys will be used to produce a site-specific QMRA.

Factor	Parameter	Variable	Units	Point Value/Stochastic	Distribution	Source
Rotavirus concentration in soil		C	copies/g	Point	Information pending	qPCR data
Hand to Mouth events	For children ages 7-12	H_{mouth}	events/hr	Point	18.5	a) Beamer, et al., 2011 b) Parent and teacher survey responses
Hand-Soil loading		H_{soil}	mg/cm²	Stochastic	Uniform min = 0.11 max = 0.17	EPA, Child Exposures Handbook, 2008
Children's hand size	7 – 13 yrs old	H_{child}	cm²	Stochastic	Uniform min = 71; max = 89.7	Choi, et al., 2011
Outside time		O_{time}	hr/day	Stochastic	Information pending	Teacher survey responses
Soil-Mouth transfer	thumb sucking finger mouthing palm licking	T_{SM}		Stochastic	Triangular 0.09 0.14 0.165	Hsi, et al., 2018
Transfer microbes hand to mouth		T_{MM}		Point	0.34	Rusin, et al., 2002

Figure 2. Exposure values from the literature to be accounted for in the Risk Characterization.

OUTPUTS & OUTCOMES DURING CLIMAS FELLOWHIP

CHSS and UA ENVS put together a soil sampling plan for areas within and around the school. Input from Naco Elementary School's principal helped inform the sampling sites. Samples were collected in February, April, and July 2019. None of these sampling events coincided with heavy rains nor SSOs. In preparation for such events, CHSS Environmental Health Specialist was trained by UA ENVS on soil and water sample collection and storage, and field testing for total coliforms and *E. coli* following a modified method from Aquagenx *E. coli* and total coliforms water quality test kit. CHSS was provided with an instruction manual as well as all needed materials.

When starting a new partnership with a school, it is vital to build strong networks with administrative staff, teachers, parents, and students. At the School Board meeting in May 2019, UA ENVS presented the project's proposal for approval of student, staff, and parent participation. At the meeting, parents, teachers, the principal, and the school board was present and were able to ask questions. The School Board's approval was recorded. During the last day of Summer School, a group of UA ENVS students worked with two groups of students in an activity relating environmental quality and health. UA ENVS went back during the school's Back to School Night at the beginning of Fall 2019. Students were able to participate in age-appropriate science activities provided by the UA's Arizona Project WET-Tucson Education program. While students engaged in these activities, parents and guardians answered the parent surveys. Surveys were available in English and Spanish. These were administered online using the Qualtrics software (Qualtrics, Provo, UT, 2019) through iPads, or by paper depending on the parent's preference. Surveys to teachers and the school's principal were administered online through Qualtrics.

Throughout our work, I have been in constant communication with ADEQ's OBEP specialist assigned to Naco. Their efforts focused on working with Sonoran water government agencies to provide maintenance and improve on water infrastructure to avoid future SSO events. Their efforts have been successful as there have been no more SSOs since December 2018. ADEQ's OBEP specialist asked us to share our project's findings, however, CHSS has asked for results to be withheld until the project's completion (May 2020).

Other outputs include presentations at the University of Arizona's Earth Week poster session, and at forum Border Health: Information for Action/Salud Fronteriza: Información para la Acción held in Nogales, Sonora, Mexico. This opportunity was very valuable as I had the opportunity to speak to community members, professionals, and researchers working in U.S.-Mexico public health related efforts. ADHS OBEH was also in attendance and I was able to update them on the progress of our project.

This research project has also served as research experience for an undergraduate student in my lab. He has assisted in sample collection, lab preparations, and in outreach events. He is now part of the UA ENVS Accelerated Master's Program and has expressed interest in using his thesis project to explore binational environmental science efforts.

LESSONS LEARNED

The initial objectives of our partnership with CHSS focused on the potential environmental and health impacts of the areas impacted by wastewater. As we expanded our conversation and reached out to Naco Elementary School, our focus shifted to solely focus on the flow by the school that posed a greater exposure risk to the children. Research that stems from community inquiry presents a valuable opportunity as people have a greater motivation to engage and learn when the subject matter directly applies to their lives (Ramirez-Andreotta et al., 2015). A main output of this project is the educational material that will be produced with the research results. A larger awareness around SSOs, their potential risks, and precautionary actions to take, could be better received by engaging in the direct needs of Naco Elementary School.

Sometimes, community champions unfortunately leave. Thus, it is important to build relationships within an entire organization rather than with a single representative of an organization. This was a valuable lesson when there was an unexpected change of principal at the school. When the change occurred, we had the signed approval from the School Board, and had communication with the school's secretary who helped set up a meeting with the new school's principal. Having already connections at the school helped us gain the support of the new principal.

There were several unexpected setbacks that changed the timeline and type of samples we hoped to have. For example, CHSS was unable to collect samples during Summer monsoon due to a faulty freezer that did not reach the temperature necessary to hold samples. A lag in communication prevented us from overcoming this drawback during Summer monsoon. However, we plan to collect samples during Winter rains. The qPCR instrument at the UA WEST Center was out of order until November 2019 which delayed our lab analysis of the samples.

Use-inspired and engaged research requires large amounts of time and effort by all involved parties to develop trust, confidence and direction. All while accounting for varying internal priorities, structural changes, and schedules. I truly believe my learning as a graduate student has been enhanced by being able to participate in meaningful applications of academic concepts. It has forced me to consider perspectives in the social and political domains beyond traditional scientific skills.

FUTURE STEPS

The partnerships and project will continue beyond the CLIMAS fellowship year. We will collect our final samples in February, and with the new qPCR instrument in place, we are now conducting test runs to optimize parameters for our samples. Once laboratory data is available and all survey answers are in, the information will be input to finalize the risk characterization. Dr. Kelly Reynolds from UA's College of Public Health is assisting me with this portion.

CHSS and UA ENVS will co-create educational material in English and Spanish to distribute to the Ambos Nacos communities during result sharing. Our hope is this information can be used to inform the school's decision on whether to move forward with the school garden and nature path, and to take necessary precautions during SSO events.

Several teachers and the school's principals have expressed needs and interest in partnering with the University of Arizona in future projects to address these needs. Many times, resources are spent on larger urban border cities and smaller rural towns such as Ambos Nacos do not benefit from the same resources and collaborative knowledge that can be produced through collaborative research. My hope is that the lab I am a part of, the Integrated Environmental Science & Health Risk Laboratory, continues these partnerships.

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Working together to serve our communities through science

What are sewage overflows?

Sewage overflows are untreated wastewater which may carry sewage, industrial wastewater, and stormwater. The causes are varied but can include improper sewage design and overload to the system. Because sewage overflows carry raw sewage, high concentrations of infectious organisms may pose a risk to human health[1].

Objectives of this study:

Cochise Health and Social Services (CHSS), Naco Elementary School, and the University of Arizona Environmental Science department are working together to determine potential health risks to Naco Elementary students as a result of the historic sewage overflows.

Community Input:

Hearing from parents, students, teachers, and other members of the community is extremely important when studying the true risk. We appreciate your input. All results will be shared with the community at the conclusion of the project. Results can help inform future land use decisions at the school and improve risk communication.

Sewage Overflow in Both Nacos (Ambos Nacos) October 2018

Environmental Science

Reference: [1] Environmental Protection Agency. "Sanitary Sewer Overflows (SSOs)" https://www.epa.gov/npdes/sanitary-sewer-overflows-ssos

Questions or Comments? We are happy to hear from you!

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Trabajando juntos para servir a nuestras comunidades a través de la ciencia

¿Qué son los desbordamientos de aguas residuales?

Los desbordamientos de aguas residuales son aguas negras sin tratar cuales pueden contener desechos industriales y agua de lluvia. Las causas pueden ser muchas. Por ejemplo, diseños inadecuados del sistema de alcantarillado o sobrecarga al sistema. Debido a que los desbordamientos llevan aguas no tratadas, las altas concentraciones de organismos infecciosos pueden representar un riesgo para la salud pública[1].

Objetivos del estudio:

Cochise Salud y Servicios Sociales (CHSS por sus siglas en inglés), la escuela primaria de Naco, y el departamento de Ciencias Ambientales de la Universidad de Arizona, están colaborando para determinar los posibles riesgos a la salud de los estudiantes de la primaria de Naco a causa de los desbordamientos de aguas residuales en esta zona.

Participación comunitaria:

Es muy importante tomar en cuenta las experiencias de los padres de familia, estudiantes, maestros, y otros miembros de la comunidad para poder evaluar el riesgo efectivamente. Apreciamos su colaboración. Al concluir el proyecto, todos los resultados serán compartidos con la comunidad. Los resultados podrán ayudar a informar decisiones en un futuro respecto al uso de terreno escolar y mejorar la comunicación de riesgo.

Desbordamiento de aguas residuales en Ambos Nacos; octubre 2018

Referencia: [1] Environmental Protection Agency. “Sanitary Sewer Overflows (SSOs)” https://www.epa.gov/npdes/sanitary-sewer-overflows-ssos

¿Preguntas o comentarios? ¡Queremos oír de usted!

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