WSUP | Water & Sanitation for the Urban Poor

Urban Sanitation Research Initiative

RESEARCH CALL
Modelling faecal pathogen flows in urban environments

This research project is commissioned under the Urban Sanitation Research Initiative, a 2017–2020 research programme (www.wsup.com/research) core-funded by UK aid from the UK government, and managed by Water & Sanitation for the Urban Poor (WSUP). The research will develop, apply and validity-test a modelling approach for understanding faecal pathogen flows within a defined urban location (in Bangladesh, Ghana, Kenya, Madagascar, Mozambique or Zambia). This will likely require significant on-site data collection to feed the model and to test its validity. A possible modelling framework has already been developed in an earlier concept study under the Urban Sanitation Research Initiative, but we are open to considering other frameworks and approaches. While this research aims to develop an internationally useful modelling approach, we would also expect it to be useful and influential in the specific location in which it is developed.

Maximum budget under this Call: *GBP 250,000 inclusive of VAT*
Bids due: *Before UK 1700 hours on 22nd October 2018 (6 weeks after release 10th September 2018)*

1 About Water and Sanitation for the Urban Poor (WSUP)

WSUP is a not-for-profit company that helps transform cities to benefit the millions who lack access to water and sanitation. We were created in 2005 as a response to the unprecedented urban explosion that has left cities unable to provide basic services, such as access to a toilet or drinking water, to low-income communities. We are based in the UK with offices in six countries in sub-Saharan Africa and Asia. Since inception we have helped nearly 15 million people access better water and sanitation services.

WSUP has grown rapidly to a £10-12m organisation and has plans for greater expansion over the next few years. The organisation is now at a pivotal stage in its growth. In the business plan period 2016-2020, WSUP's ambition is to raise £65 million (an annual turnover of up to £18-20 million in FY2019-20), but more importantly to be recognised as a key player in the water and sanitation section sector globally. It presently operates six well-developed, respected country programmes in Africa and Asia to

strengthen public and private sector service providers to improve the delivery of affordable services to low-income customers. WSUP has recently expanded its portfolio of operations to include the building and strengthening of private sector provision in urban water and sanitation services and the sale of consulting services on all aspects of low income urban WASH (Water, Sanitation and Hygiene) to disseminate learning and increase impact. All of these operations are supported by research, communications, funding and finance and resources teams. For more information about WSUP's vision and approach, see www.wsup.com

2 About the Urban Sanitation Research Initiative

This research is being commissioned under the WSUP-led Urban Sanitation Research Initiative (www.wsup.com/research). The Urban Sanitation Research Initiative is a 2017–2020 research-into-policy programme focused in Bangladesh, Ghana and Kenya. The primary aim of this initiative is to deliver research that builds national evidence bases around pro-poor urban sanitation, and that drives policy change and wider sector change in the three focus countries. The initiative is managed by Water & Sanitation for the Urban Poor (WSUP) and core-funded by UK aid from the British people.

The Urban Sanitation Research Initiative focuses on five broad areas: 1) sanitation businesses and market development; 2) institutional frameworks and capacity; 3) sanitation models, user behaviour, and user experience; 4) public finance and sanitation planning; and 5) regulation and smart enforcement. This Call relates most closely to Areas 3 and 4.

For more information about the vision and aims of the Urban Sanitation Research Initiative, and for information about other Calls, see www.wsup.com/research

2.1 Sector influence aim

This work will develop a modelling approach that, if demonstrated to generate reliable predictions, can support context-specific decision-making around the most cost-effective interventions to reduce disease burden due to faecal pathogens in low-income urban contexts.[1] Unlike in most research projects under the Urban Sanitation Research Initiative, immediate policy influence should *not* be a core priority for the researchers, who should focus available resource on technical aspects of model development and testing. However, if this model is able to develop reliable predictions in the model-development location, the findings of this work will be used by WSUP to support ongoing sanitation planning in that city. Further, we expect that this work will generate internationally valuable knowledge **a)** around how to model faecal pathogen flows in urban environments, and more specifically **b)** around liquid leaching from septic tanks, and around the extent to which tank emptying can reduce such leaching, and this may have significant international impact on the policies and practices of development funders and implementing agencies.

[1] Notwithstanding this eventual aim, we do not expect researchers to look at costs under this contract; rather, we expect this contract to focus resource on pathogen flows modelling: see Section 3.2.3.i.

3 Nature of the research

3.1 Background

3.1.1 Why is system modelling of faecal pathogen flows of potential value?

The core justification for spending government and ODA money on urban sanitation is health, particularly child health; health is often not the key driver of household investment, but it's the core justification for government/ODA spend.

There are strong theoretical grounds (and limited empirical evidence) for supposing that adequate urban sanitation is critical for health. But there is still very weak understanding of exactly what an urban sanitation improvement needs to look like in order to achieve health impact, and of what other types of improvement (e.g. in food hygiene) are necessary in parallel (Esteves Mills & Cumming 2016).[2]

A consequence of this is that many sanitation investments are based on shaky theories of impact. For example, development agencies are currently investing significant resource to support improved emptying of septic tanks, on the explicitly or implicitly stated view that this will improve health by removing pathogens from the populated environment. But many interventions of this type pay little attention to the (often plausible) possibility that septic tanks may be dysfunctionally releasing large quantities of faecally contaminated liquid, such that improved emptying may (?) have little real impact (Mitchell et al. 2016).[3]

One approach to generating better evidence in this area is to use RCTs or related quasi-experimental approaches to evaluate the impacts of different types of intervention. RCTs are very powerful in terms of internal validity; but this approach also has profound limitations in the urban sanitation context, including but not limited to **a)** questionable generalisability of findings from the study context to other contexts, and **b)** a sort of "tunnel vision" arising from the fact that such studies are very powerful for assessing the magnitude of effect of a particular intervention, but not nearly so powerful for understanding the relative importance of the different possible causal components of a complex intervention mix.[4] RCTs of sanitation interventions are also hugely expensive.

If we want to compare different sanitation investment scenarios in City X, in terms of cost-effectiveness for health impact reduction, we can use crude approximations of the likely health impact of different investments from pooled estimates derived from meta-analyses of impact evaluation studies of this type. Such pooled estimates are of highly questionable value.[4]

An alternative approach is to develop a better understanding of the "complex system" of faecal pathogen flow pathways in that specific city, using a combination of local primary data and data drawn from the international literature, brought together and analysed through a system modelling approach (i.e. mathematical simulation of faecal pathogen release, transport and human exposure leading to disease) in that particular city.

Such an approach faces very significant challenges (most notably, the need for high-quality data, and issues of garbage-in-garbage-out). But impact evaluation also has major drawbacks, for the reasons outlined above. Neither can alone generate complete answers to the practically relevant questions: but together, we suggest that they can build a more complete and evidence-based picture, in specific contexts and more generally.

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[2] Esteves Mills J & Cumming O (2016) The Impact of Water, Sanitation, and Hygiene on Key Health and Social Outcomes: Review of Evidence. DFID Evidence Paper produced by SHARE and UNICEF.

[3] Mitchell C, Abeysuriya K & Ross K (2016) Making pathogen hazards visible: a new heuristic to improve sanitation investment efficacy. Waterlines 35:2, 163-181

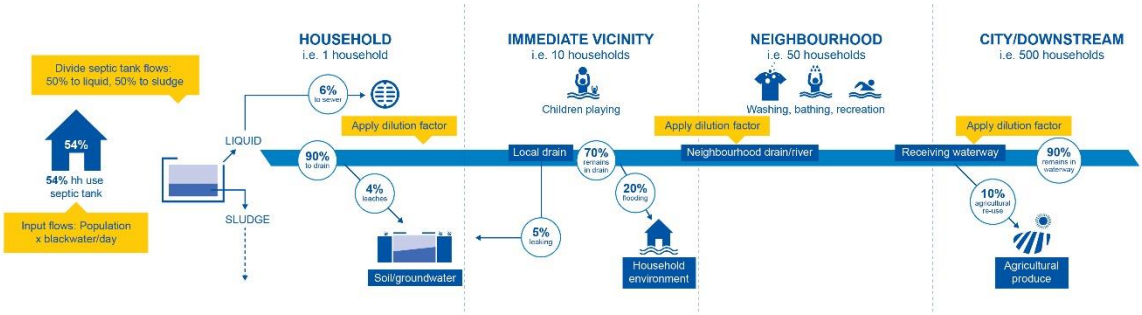
[4] See for example Schmidt W (2014) The elusive effect of water and sanitation on the global burden of disease, Trop Med Int Health, 19: 522-527; and Carter R (2017) Can and should sanitation and hygiene programmes be expected to achieve health impacts? Waterlines, 36-1: 92-103. In a recent publication, researcher Steve Luby writes that "We do not have strong evidence about the relation between sanitation and health because such data are difficult and expensive to generate. Environments highly exposed to faecal pathogens are remarkably diverse. […] The relative importance of sanitation in the interruption of pathogen transmission almost certainly varies by community."

This research will therefore attempt to develop a system modelling approach to understand faecal pathogen flows, in a defined urban location. As detailed below, this work will certainly require field data collection to feed the model and to test the validity of its predictions.

3.1.2 A possible modelling approach

A previous concept study commissioned by the Urban Sanitation Research Initiative has developed a possible framework for modelling faecal pathogen flows.[5] The basic steps of this approach can be briefly summarised as follows:

A) Identify the main original sources of faecal pathogens (e.g. septic tanks, latrines), and estimate **volumetric flows** along different potential pathways, as in the following schematic example (which shows pathways arising from one particular category of release of faecal waste, namely liquid release from septic tanks):



B) Using published or local data on pathogen loads in excreta, and estimates of rates of die-off in treatment systems and the environment, estimate **pathogen flows** (on the basis of the volumetric flow estimates). This is done separately for different major pathogen groups.

C) By summing the pathogen flows estimated from each source compartment, estimate resulting **pathogen concentrations** in each exposure compartment (in the schematic above: groundwater; household environment; local drain; neighbourhood drain; fresh agricultural produce; receiving waterway).

D) Use behavioural data and a Quantitative Microbiological Risk Assessment (QMRA) methodology to estimate the **disease impact** (in disability-adjusted life years lost = DALYs lost) of each pathogen via each exposure compartment, on the basis of pathogen concentration (applying a dose-response model) together with expected frequency of exposure, and proportion of population exposed.

E) The model can then be varied by introducing changes corresponding to candidate sanitation improvements: for example, what happens if we move 10,000 people from septic tanks to sewer; or if we increase sludge removal rates by 25%; or if we reduce groundwater use by half?

This simple framework makes clear logical sense, but of course raises multiple questions around how to obtain input data of sufficient quality to generate reliable findings: this is discussed in more detail in Section 3.2.3.g below.

This framework is certainly not the only possible framework for modelling faecal pathogen flows in urban environments, and as discussed in Section 3.2.3.c below, it is not a requirement that bidders adopt this

[5] Mills F, Willetts J, Petterson S, Mitchell C & Norman G. Faecal pathogen flows and their public health risks in urban environments: a proposed approach to inform sanitation planning. Int. J. Environ. Res. Public Health, 15: 181.

approach or a close variant of it. However, we note that this type of framework offers strong advantages in terms of practical utility, essentially because it is a "white box" ("mechanistic") approach as opposed to a "black box" ("empirical") approach: in other words, it attempts to map out causal pathways, and we consider that this is likely to be of much stronger practical value than a "black box" approach. As a hypothetical example of a "black box" approach, we might imagine a model based on extensive analysis of descriptive data (e.g. official survey data, clinical records data and satellite imagery data) for city districts in multiple cities and countries, aiming to identify predictive relationships between *sanitation type* and *health*, and with the model likely treating district characteristics other than sanitation type (e.g. demographic and hydrogeological characteristics) as potential effect mediators. Such a model would not include consideration of casual pathways intermediate between the district characteristics treated as model input parameters and the eventual health outcomes predicted, and as stated we consider that a "white box" approach is of greater value.

3.1.2 System modelling more widely

We (the authors of this Call) do not have detailed knowledge or understanding of system modelling, but certainly we are aware that approaches broadly classifiable as "system modelling" have been applied to diverse types of problem in public health and environmental health. Recent systematic reviews include Carey et al. (2015), looking broadly at "systems science and systems thinking" in public health, and Currie et al. (2018), looking more specifically at the application of "system dynamics modelling" to environmental health decision-making and policy. These authors note multiple applications of system modelling in areas including infectious disease transmission, virus spread facilitated by air travel, public policy around issues like tobacco cessation, and urban planning including for example relationships between urban transport policy and respiratory disease. The nature of the modelling approach used varies widely. Carey et al. (2015) note that public health research that uses system modelling techniques "often fails to assess whether the models constructed therein are any good": in other words, few studies incorporate model validation.

System modelling approaches are also very widely used to understand pollution processes, including modelling of the environmental fate of pollutants or pathogens in surface and subsurface waters (essentially one component of the framework proposed by Mills et al. 2018). For a recent review of system modelling of water use/quality at the watershed level, see Daniel et al. (2011).[6]

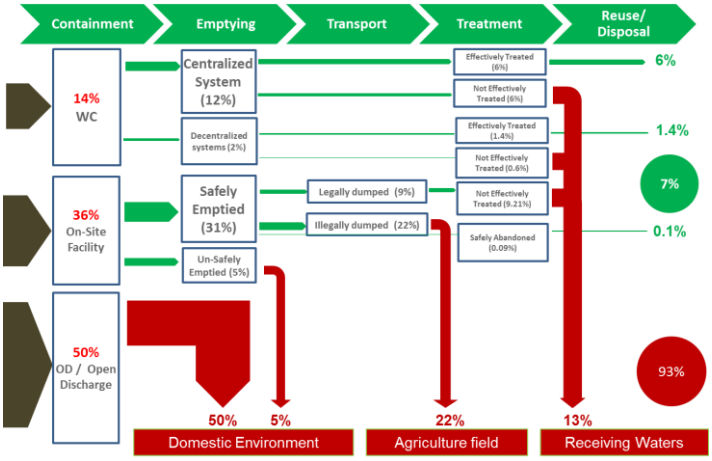
We are not aware of previous work closely analogous to the work of Mills et al. (2018) outlined above. Rydin et al. (2012) argue that urban health needs to take a complex systems perspective that brings together consideration of multiple types of environmental intervention, including sanitation improvement. These authors present an interesting schematic of relationships between sanitation and water supply, and of their complex impacts on health: but this is simply a summary schematic, not an attempt at quantitative modelling. Holderness et al. (2014)[7] used network modelling to evaluate the transport costs of tankered removal of faecal waste, but this is only tangentially related to the research aims outlined here. Much more closely related is the SaniPath approach,[8] which uses relatively simple modelling to identify highest-risk events for exposure to faecal pathogens, on the basis of environmental sampling to quantify faecal pathogen levels in different exposure compartments (e.g. soil within housing compounds, open drains, unwashed raw vegetables) and behavioural data collection (e.g. observations

[6] Daniel EB, Camp JV, LeBoeuf EJ, Penrod JR, Dobbins JP & Abkowitz MD (2011) Watershed modeling and its applications: A state-of-the-art review. The Open Hydrology Journal, 5(1).

[7] Holderness T, Kennedy-Walker R, Alderson D & Evans B (2014) An Evaluation of Spatial Network Modeling To Aid Sanitation Planning In Informal Settlements Using Crowd-Sourced Data. In: Campbell P. and Perez P. (Eds), Proceedings of the International Symposium of Next Generation Infrastructure, 1-4 October 2013, SMART Infrastructure Facility, University of Wollongong, Australia.

[8] Wang Y, Moe CL, Null C et al. (2017) Multipathway quantitative assessment of exposure to fecal contamination for young children in low-income urban environments in Accra, Ghana: the SaniPath analytical approach. Am J Trop Med Hyg 97 (4), 1009-1019. For other publications see http://sanipath.org/knowledge-products/publications/

of how frequently children make contact with open drains). This approach can be considered closely analogous to steps C and D within the modelling framework proposed by Mills et al. (2018) [see above]. The "shit flow diagram" (SFD) approach[9] initially developed by the Water and Sanitation Program (WSP) of the World Bank also shows some conceptual parallels to the modelling framework proposed by Mills et al., though at a much lower level of complexity. Specifically, an SFD is a schematic showing the estimated proportion of faecal waste in a given city that flows along different major pathways, as in the example below for a city in India (green = safely managed, red = unsafe). Percentage values for each component of the pathway are typically estimated on the basis of existing data sources, such as household survey data and treatment plant records.



3.2 Aims, approach and design

3.2.1 Over-arching aims and approach

The aim of this research is to develop, apply and validate an approach for modelling faecal pathogen flows in urban environments. The model should be developed in a defined location, likely a defined district of a city to be identified at bidding stage (see Section 3.2.3.a). This work will almost certainly require targeted data collection to generate input data and validation data (see Section 3.2.3.b). At this stage, we expect that the best approach will be to take the Mills et al. (2018) framework as the basis for this work, and to develop that model, a close variant of it, or a reasoned sub-component of it; however, we do not rule out different approaches that align with the over-arching aims of this Call (see Section 3.2.3.c). Those over-arching aims can be summarised as follows:

- **We require a modelling approach that, if demonstrated to generate reliable predictions, can in future support context-specific decision-making around the most cost-effective interventions to reduce disease burden due to faecal pathogens, in low-income urban contexts (as common in sub-Saharan Africa or South Asia).**[10] Within the lifespan of this contract, this is understood to refer to decision-making in the model development location; however, beyond the lifespan of this contract, the modelling approach should be potentially applicable in other low-income urban contexts worldwide.

[9] https://sfd.susana.org/about/the-sfd

[10] This statement refers to the long-term aims of this work: but as noted below, we do not expect costing to be considered in the present contract (which should focus on pathogen flow modelling), and we are open to bids which choose to focus on more proximate end-outcomes (e.g. a metric of exposure risk, rather than a metric of disease burden: see 3.2.3.g).

- Validity testing will be key (see Section 3.2.3.f below): given the very significant known challenges of data availability and data quality, we might paraphrase the aims of this research as "*give it your best shot in a given location, then rigorously assess whether your model really works*".

- We note a specific interest in one particular aspect of the pathogen flows "puzzle". Specifically, we suspect that liquid discharge from septic tanks (to groundwater, or to open drains) is commonly under-rated as a source of pathogen release (Mitchell et al. 2016),[11] and we are interested to understand whether that is the case in the model development location, and to understand the likely impact of septic tank emptying practices on that discharge component. We would therefore prefer that this work be done in a location in which septic tanks are a common solution, and that this component of the model receive particular attention: this should not be challenging, since poorly functional septic tanks are widespread in cities in sub-Saharan Africa and South Asia (though certainly, there is wide variation in multiple relevant factors including hydrogeological conditions affecting leaching from septic tanks to groundwater, and importance of groundwater as a drinking water source).

3.2.2 A possible outline design

One possible outline design for this work, based on development and application of the Mills et al. (2018) framework, would be as follows:

a) Identification and initial characterisation of a model development location (e.g. a defined administrative or topographical district of say 500-5000 households in a city in Bangladesh, Ghana, Kenya, Madagascar, Mozambique or Zambia).
b) Initial pre-implementation of the model using existing local data, data from the international literature, and expert judgement; identification of data gaps, and in particular of those data gaps that can most cost-effectively filled by local empirical data collection within the lifespan of the current study (see comments on sensitivity analysis, Section 3.2.3.f).
c) Data collection.
d) Full model development.
e) Validity testing (see Section 3.2.3.f).
f) Model finalisation, documentation and reporting.

This is a grossly simple or simplistic summary of what a study design might look like, but we hope it gives some understanding of the scope of work we require. We will expect bidders to give a detailed summary of their proposed design at bidding stage, though we fully accept that some aspects of design may be left open pending early-stage exploratory work.

3.2.3 Clarifications

a) Where should we develop this model?
We would initially anticipate that the model should be developed for a meso-scale urban location, e.g. a defined administrative or topographical district of a city, with population of that district perhaps 500-5000 households. Our preference is for this work to be done in a city in Bangladesh, Ghana or Kenya (the focus countries of the Urban Sanitation Research Initiative, with existing WSUP staffing to support research work and policy translation). However, we would also be willing to consider work in the other countries in which WSUP has a permanent presence (Madagascar, Mozambique and Zambia).

[11] Mitchell C, Abeysuriya K & Ross K (2016) Making pathogen hazards visible: a new heuristic to improve sanitation investment efficacy. Waterlines 35:2, 163-181

Possibly suitable cities in which WSUP has a strong and established presence (which can facilitate this research and its policy uptake) include: Rangpur, Dhaka and Chattogram (Chittagong) in Bangladesh; Accra and Kumasi in Ghana; Nairobi, Nakuru, Malindi and Mombasa in Kenya; Antananarivo in Madagascar; Maputo in Mozambique; and Lusaka in Zambia. WSUP's current preferred location for this research is perhaps Chattogram (Chittagong); but this is not a strong preference, and proposed location (as long as well justified) will not be a major determinant of bid evaluation.

b) What sort of data collection might be required?

We certainly expect that extensive local data collection will be required for both model development (i.e. input data) and for validity testing (see 3.2.3.f below). Bidders should offer (at the bidding stage) at least a provisional identification of likely data collection needs and outline methodology. Possible data collection might be around: microbiological analysis of pathogens in different initial source compartments, including liquid leachates from septic tanks;[12] microbiological analysis of pathogens along different pathways and in different exposure compartments, along the lines of Sanipath (e.g. in drinking water from different sources, in soil close to living spaces, in open drains close to living spaces, etc); behavioural observation at different exposure points, again along the lines of Sanipath; possible empirical studies of pathogen transport and inactivation in different model compartments [see also 3.2.3.g below]. We note that weather seasonality (particularly rainfall) will undoubtedly be relevant, and bidders will need to consider how they will deal with this in the short timespan available for this work.

c) Are bidders required to follow the Mills et al. (2018) model?

We anticipate (but do not require) that the modelling approach would be essentially similar to that of Mills et al. (2018), in the sense that it would be centred on a simulation model of pathogen flow pathways in the urban environment. The key practical advantage of this approach is that it encourages in-depth understanding of different pathogen flow components, with heuristic value (e.g. indication of where data gaps are most significant) as well as evidential value. [It is arguably also easier to empirically assess the internal validity of a disaggregated causal model of this type, for example by using dye tracing to confirm predictions about volumetric flow pathways; see Section 3.2.3.f.] We stress, however, that we are open to different modelling approaches which fulfil the over-arching aims of this Call as defined in Section 3.2.1. Equally, bidders may propose approaches which essentially follow the Mils et al. framework, but which focus on a subset of pathways, and/or focus on a more proximate end-outcome (e.g. exposure risk; see Section 3.2.3.g). *If you wish to propose a different type of model or a significant variant of the Mills et al. model, we are very happy for you get in touch with us directly before submission (erl@wsup.com), with a very brief outline (no more than 100 words) of what you are proposing, to get our initial view on whether we consider that it aligns with the core aims of this research.*

d) Which pathogens, which human exposure groups?

Bidders should propose the faecal pathogen/s that they will focus on for the purposes of this research. Possible approaches include **a)** focus on a single pathogen judged of strong relevance on one or more criteria; **b)** focus on a single pathogen judged to be a good indicator (though this would need to be adequately justified); **c)** focus on a small subset of pathogens identified as usefully representative on one or more criteria; **d)** consideration of a longer list of pathogens. Bidders should give reasoned explanation of their choice. Bidders should similarly propose the human exposure groups to be considered: possible approaches include **a)** children under 5 only, **b)** children under 5, older children, adults, **c)** children under 5, older girls, older boys, women, men. There would be evident arguments for focusing the limited available budget on (a) only, but bidders are free to make other reasoned proposals.

[12] In many locations, there is frequent direct liquid overflow from septic tanks to open drains, which is clearly much easier to monitor than subsurface leaching.

e) To what extent do you expect us to generate a finalised model?

We require this research to develop a finished and functioning model (i.e. we are not looking for some sort of initial concept/scoping study), and we expect significant internal validation within the contract period (see Section 3.2.3.f). We require the model (e.g. in Excel implementation) to be readily comprehensible to and usable by others, but we do not expect development of a sophisticated interface; in other words, we are interested at this stage in model development, application and validation for this specific location, not in the development of a sophisticated generalisable tool for application of the model in other locations (though certainly we might look for that in future contracts).

f) What do you expect in terms of validity testing?

We are looking for internal validity testing (i.e. assessment of whether the model is generating reliable predictions in the model development location); we absolutely understand the value of validity testing in other locations, but we do not expect this in the present contract. Validity testing will certainly be challenging. Within the lifespan and budget of the present contract, it will almost certainly be impossible to assess internal validity in terms of health end-outcome (reduction in disease risk or disease burden, or similar health metric), because of multiple methodological barriers. Rather, we suggest that internal validity can be assessed by identifying key intermediate predictions within the model that can be empirically tested by techniques such as tracer studies or microbiological analysis of environmental samples.[13] Validation might also be achieved by triangulation against other existing data sources, e.g. existing water quality surveys. Related to validation, we would expect robust and extensive sensitivity analysis to explore sensitivity of model-predicted outcomes to variation in different input parameters: we understand that this can **a)** identify most critical data gaps; **b)** help assess which intermediate predictions are most influential for end-outcomes, and thus which intermediate predictions are most usefully checked by empirical validation; and **c)** can generate confidence limits around predictions. We expect bidders to pay careful attention to sensitivity analysis and model validation in their bids; we are not subject experts ourselves, and bidders will likely have much better understanding of possible approaches to validation and sensitivity analysis than us. We imagine that validation should be based on new data, not on the data used to construct the model; if you disagree, please make explicit your proposed approach and reasoning.

g) Will it be possible to develop a model which generates reliable predictions?

We don't know. The challenges around availability and cost of collection of sufficiently accurate input data and model parameters are very significant. We expect researchers to give it their best shot, and to rigorously test the validity of the model.[14] We anticipate data availability/reliability challenges in multiple areas including: persistence of different pathogens in different environmental compartments, with much existing data from temperate not tropical locations, and with likely influence of context-specific hydrogeological and edaphic factors; apportioning of different pathogens between solid and liquid factions in septic tanks; settling rates for pathogens (especially larger pathogens, i.e. helminths and protozoa) in water courses; see Mills et al. (2018) for more detailed discussion. As noted by Mills et al. (2018), another significant difficulty is around infection dose-response functions, typically derived from challenge studies in wealthy temperate locations: but certainly, we don't anticipate that this contract could deliver local challenge studies of this type. This type of difficulty will require researchers to carefully consider what the most appropriate end-outcome might be: Mills et al. (2018) propose *relative health risk*, in other words the predicted change [for any given projected intervention, e.g. "connect 50% of the population to sewer"] in disability-adjusted life-years (DALY) per person per day,

[13] Researchers might choose to do iterative rounds of modelling-validation-adjustment-revalidation etc; but of course this would need to be done in a way that ensures real increasing validity, rather than just repeated re-fitting to a new round of data.

[14] What if it becomes clear within the research period that the model has poor reliability? One possibility here will be to make a reasoned decision to shift focus to some more specific component, for example 1) a component of particular interest (e.g. septic tank outflows and impacts of emptying), or 2) a component identified by validity testing as having weakest reliability, or identified by sensitivity analysis as of most importance to better understand. Bidders may wish to consider possible scenarios in their bid.

as a percentage change [e.g. -10%, no change, +10%] with respect to the current situation. One approach which bidders may wish to consider is to focus this research on a more proximate end-outcome, such as exposure risk (based for example on projected pathogen X concentration in each exposure compartment, and behavioural data allowing estimation of probability of exposure to that compartment). Multiple other complexities arise around *temporal variability* (e.g. in rainfall); around *spatial variability and scale* [e.g. to what extent is spatial structure e.g. actual mapped locations of watercourses, relevant? e.g. to what extent can and should the model take into account the spatial density of interventions, i.e. an intervention serving all 500 people within a defined location may have a stronger effect than an intervention serving 500 people across the city]; and potentially around the *dynamics of infectious disease transmission and immunity* within populations; again, see Mills et al. (2018).

h) To what extent do you expect us to tie this to policy influence?
A central aim of the Urban Sanitation Research Initiative is to achieve real influence on policy, and we certainly understand that any modelling approach of the type would need to be integrated within a wider consultative urban sanitation planning process in order to have real-world value. However, for this specific contract we do not consider this aspect critical, and we view this as essentially technical research, with the available budget to be focused on model development and associated data collection, rather than on policy uptake. We would certainly expect the research team to gain an adequate understanding of the urban sanitation planning context in the model development location, and to be cognisant of any major upcoming investments. But we prefer this research to focus on technical aspects of model development. WSUP and other partners of the Urban Sanitation Research Initiative may certainly use findings of this research to drive policy change in the model development location and elsewhere.

i) Do you expect us to cost different candidate interventions?
No. We certainly understand that eventual real-world application of a modelling approach of this type would need to incorporate financial cost estimates for different candidate interventions (as per Step E in Section 3.1.2 above). But we consider this as secondary at this stage, and strongly prefer to focus the available budget on development/validation of pathogen flows modelling and associated data collection.

3.3 Core requirements for work under the Urban Sanitation Research Initiative

The following are core requirements for work carried out under the Urban Sanitation Research Initiative:

1) **Research must fully meet relevant research ethics requirements:** All research must be carried out in compliance with research ethics standards as rigorous as would be applied in a UK setting, and in compliance with the law and with best practice in the country or countries in which research is carried out.
2) **Research design should pay careful attention to gender equality/equity considerations:** Bidders should explicitly ensure that their proposed design, analysis and research-into-policy work is taking full account of gender equality and equity. [*In the present context, bidders may decide that a specific focus on gender issues is secondary to this research aim, and does not merit budget allocation; conversely, one possible approach would be to explicitly consider differences in exposure pathways between men and women, or to focus on exposure pathways for women, though we note that the primary exposure of interest will likely be children under 5.*]
3) **Research-into-policy should be considered a core element:** Research-into-policy should be considered a core element at all levels and stages of research design; not an after-thought once the “real research” has been completed. [*But see 3.2.3.h above, which somewhat relaxes this requirement for this project.*]

For more detailed explanation, see the Core Requirements Form attached as Appendix A, which must be completed by all bidders and submitted with the bid (see Section 9).

3.4 Deliverables

The following deliverables are required:

a) an inception report for WSUP detailing the methodology to be followed, within 6 weeks of project start;

b) brief monthly email updates on progress (bulletpoint format is sufficient);

c) six-monthly reports on progress (likely around 3 pages);

d) the final model implementation (in Excel or other platform) and full data-set, with sufficient internal clarity for use by other people, or failing that with sufficient separate explanatory documentation;

e) at least one, likely more, journal publications describing the model, its application and validity testing to an international audience. [*Given the tight timespan available for this research, we are able to consider one publication submitted within contract period, other publications to be submitted subsequently. Being able to offer more than one publication submitted within the contract period will of course be viewed favourably; but in the final analysis, our interest is in an academic publication plan which ensures that this work is fully and comprehensively reported to international audiences, in however many publications that might require; if that can be done in just one journal publication, fine.*]

The inception report (a) must include a specific short section indicating how the Core Requirements (Appendix A) will be met.

All deliverables (including draft-stage submissions) should be written and laid out to publication-ready standard, with strong attention to clarity of structure, quality of wording, and professional layout; reports of poor quality will not be accepted.

Deliverable/s (e) should be written as a journal article in the format of a named journal, not as a report for WSUP or country-level stakeholders. We (WSUP and the partners of the Urban Sanitation Research Initiative) expect to have full opportunity, with sufficient time allocation, to review and respond to research papers in journal article format; we reserve the opportunity to withhold corresponding payment until we are satisfied with the quality of each paper, which may require no modifications, minor modifications, or major modifications. Our focus will be on methodological/intellectual quality (to the extent that we are qualified to judge this) and readability; if there is any disagreement about interpretation of findings and questions of judgement, we will request that our views be given sensible consideration, but in the final analysis respect the researchers' academic independence.

If the researcher judges it necessary, WSUP will respect embargo on reporting findings to be published in a peer-reviewed journal. However, WSUP will expect to be able to make public headline findings (typically understood to mean any content that is included in the Abstract, though with re-wording, and potentially including basic methodology detail and headline findings not included in the Abstract but required for reasonable understanding of the study's central findings) before journal publication. We expect a mutually constructive approach on this: WSUP recognising that the researcher may not be able to make full findings public before journal publication, the researcher understanding that WSUP must have the option to immediately disseminate headline findings to key audiences.

3.5 Schedule

Date	***Milestone/deliverable***
Before UK 1700, 22nd October 2018	*Bid submission (6 weeks after release of this Call)*
Before 5th November 2018	*Preferred bid selected, bidders informed*
Before 5th December 2018	*Contract agreed and signed*
No later than 10th January 2019	*Work start date*
No later than 21st February 2019 (ideally earlier)	*Deliverable a: inception report*
15th January 2020	*Draft deliverables d and e*
28th February 2020	*Final deliverables d and e*

We stress that this is a 15-month project with no possibility of costed or no-cost extension, and research design will need to take this into account. We note that we have allowed generous time between bid selection and work start (understanding that little can happen over the Christmas period): but this contract will require researchers to "hit the ground running" in January 2019, ideally with significant planning/review/logistics work already undertaken before Christmas. Final deliverables d and e will be the trigger for final payment.

4 Team profile

We are happy to consider any proposed team structure (i.e. any combination of universities, research institutes, research consultancies or individual consultants, with any geographic distribution) that provides the required skills and capacity. We require a single prime through which all contacts, contract negotiation and invoicing should be managed. The prime should be able to achieve strong presence in the proposed model development location (whether through existing own-staff, or through subprimes or subcontracting or other arrangement). The research team should be able to demonstrate **a)** strong understanding of urban sanitation in general; **b)** strong understanding of environmental modelling of water-borne pathogen/pollutant fates; **c)** strong understanding of infectious disease modelling; and **d)** demonstrable capacity to manage a significant research project. It is not necessary for the research lead to be expert in all of these areas, indeed it is possible that the lead's primary expertise may be in another area of environmental health modelling; but the team as a whole will need to demonstrate strong concept understanding across all areas.

5 Intellectual property

This is an academic research contract, and as such the researchers will retain full intellectual property rights for this research, subject to the deliverables requirements indicated above, but with full rights granted to WSUP immediately and in perpetuity to reproduce and use the findings of the research as WSUP deems fit, including in WSUP publications drawing on the research findings, and including by partners of the Urban Sanitation Research Initiative. In any use by WSUP or partners of findings arising from this research, the researchers will be duly credited. For full details of intellectual property rights, bidders should review WSUP's standard Research Agreement, available on request. [See also comments above under Section 3.4, in regard to publication of headline findings by WSUP and partners before journal publication.]

6 Reporting and liaison

The Task Manager for this work will be Guy Norman (WSUP Director of Research). There will be liaison with other WSUP team members as necessary.

7 Contract terms

A standard WSUP Research Agreement format will be used, subject to the Researcher's agreement with the terms.

Where the bidder is a consortium, a contract (Research Agreement) will be signed with a single prime; we cannot consider multiple contracts under a single Call.

8 Payments

8.1 Payment schedule

Payment will be 25% on contract signature, 25% on acceptance by WSUP of first 6-monthly report, and 50% on acceptance by WSUP of final deliverables. All payments will require prior invoicing.

8.2 Budget

Up to GBP 250,000 inclusive of VAT (sales tax) or other taxes; this amount will be expected to cover all costs, including any sub-contracting of staff, any travel costs, and the full costs (including venue and participant travel costs as required) of any workshops or similar meetings. Over and above this budget, WSUP will additionally consider bearing a cost of up to GBP 1,500 per journal publication, if the selected journal/s for publication of this research require payment for open-access, and if that publication is submitted to the journal within the lifespan of the present contract.

We are certainly open to match-funding proposals, i.e. bids which include offer of additional funding to expand the scope and depth of this work. We encourage bidders not to spend time detailing offers of in-kind match, which is not likely to be of significant importance to us; but certainly substantial additional funding to be dedicated to this specific work will strengthen bids.

9 Bidding procedure

9.1 Bid format

Bid format is designed to make bidding relatively easy, with a focus on the proposed methodology. Bids should be submitted to erl@wsup.com before UK 1700 hours (5 pm) of 22nd October 2018. We stress the importance of adhering strictly to the instructions below, including word counts; we do not expect to receive long standard texts detailing bidders' previous experience, over and above the requirements indicated.

The bid document should contain only the following numbered sections:

1) **Name of lead bidding organisation**
2) **Name and email of primary contact**
3) **Brief summary of relevant experience of lead organisation and other participating organisations or key individuals, indicating and describing 3 recent most-relevant projects** (*max 750 words*)
4) **Statement of the justification for and aims of this research as expressed by the bidder.** We are interested primarily in academic/technical justification, not ethical justification (*max 400 words*)
5) **Statement of the approach and methodology to be used** (*max 2000 words*). This statement can include decisions left open pending more detailed analysis, but we encourage bidders to develop a strong methodology (including clear statement of the duration and likely scheduling of all work including in-country work). [See also Section 3.3 and Appendix A.]
6) **Statement of the available start-up date and anticipated final completion date.** See Deliverables section.
7) **Statement of anticipated day allocations of all participants in the research.** Include any sub-contracted participants, with participants named as far as is possible.
8) **Summary budget breakdown in tabular form in GBP.** Clearly indicate total budget (maximum GBP 250,000 inclusive of VAT; or more if the bidder can bring match funding).
9) **Indication of first-choice named open-access journal/s for publication of this work.** Please indicate any requirement for payment for open-access.

You should also separately attach the following two documents:

A) Up to five CVs including **a) the lead researcher** (i.e. person who will take primary responsibility for design and management oversight of this research, and for research journal publication) and **b) the person with highest allocation of days.** [*This may in some cases be the same person.*]

B) A completed copy of the Core Requirements Form: see Appendix A.

In summary: your submitted bid should comprise 2 documents plus 1-5 CVs.

Please name your files as follows, where XXXXX is a single-word no-spaces summary bidder name (e.g. JENKINSON, CUNIKRI, URBANRT) of up to 10 letters:

XXXXX-bid
XXXXX-core-requirements-form
XXXXX-CV1 (etc)

9.2 Bid scoring criteria

Bids will be scored on the following criteria:

CRITERION	**Points**
a) Adherence to requirements for bid format and demonstration of clear writing/formatting skills	10
b) Quality and appropriateness of research team, as evidenced by Bid Sections 3, 7 and CVs	30
c) Strength of understanding of the research concept, and strength of methodology, as evidenced by Bid Sections 4 and 5	40
d) Demonstration that this research will effectively meet the core requirements, as evidenced by the Core Requirements Form (appendix A)	10
f) Value for money within available budget	10
TOTAL	100

9.3 Pre-submission consultation

We are very happy to respond to clarification queries of any sort prior to bid submission: please email erl@wsup.com. Where we consider that the response to a query should (for reasons of fairness) be shared with all bidders, we will do so by emailing all bidders who have already contacted us to express an interest in bidding: if you want to be included in any such mail-out, please let us know promptly.

Appendix A: Core Requirements Form

As indicated in Section 9.1, all bids should include a completed copy of this Core Requirements Form, which asks you to briefly clarify how you proposal will meet the three core requirements of research under the Urban Sanitation Research Initiative, as outlined in Section 4.

Requirement 1: Research must fully meet relevant research ethics requirements

All research must be carried out in compliance with research ethics standards as rigorous as would be applied in a UK setting, and in compliance with the law and with best practice in the country or countries in which research is carried out. We note that some types of research (*for example, a study involving invasive treatments or biopsy sampling of human subjects*) will have extremely stringent research ethics requirements; other types of research (*for example, a desk study of institutional frameworks*) will have minimal research ethics requirements, beyond the need for due rigour, balance and consultation, and informed consent in any interviews; other types of research (*for example, a study involving household survey to collect information about slum communities*) will have research ethics requirements intermediate between these two extremes. We note also that researchers must take full responsibility, at the bidding and research implementation stages, for ensuring that relevant research ethics requirements are duly met, in letter and in spirit.

QUESTIONS YOU NEED TO ANSWER: How will you ensure that your research is carried out in compliance with research ethics standards as rigorous as would be applied in a UK setting, and in compliance with the law and best practice in the country or countries in which research is carried out.

write here, maximum 150 words (please adhere strictly to this maximum word count)

Requirement 2: Research design should pay careful attention to gender equality/equity considerations

Bidders should explicitly ensure that their proposed design, analysis and research-into-policy work is taking full account of gender equality and equity. This is NOT a tick-box requirement for "including gender" in all research (indeed, bids may be scored down for "including gender" in tick-box ways which unhelpfully divert the research from its primary focus). Rather, our goal is to ensure that all bidders demonstrate that they have given serious thought to the possible implications of their research for women and girls, and include gender considerations in appropriate ways where this is important to exploration of the primary research question/s.

i) If this research in any way develops, or feeds into development of, a sanitation technology, sanitation service delivery model or sanitation policy, then this should be done in ways that ensure that that technology or model or policy fully meets the needs of women and girls; specific requirements of women and girls (including, but not restricted to, menstrual hygiene management and safety after dark) should be given due attention.

ii) If this research in any way assesses sanitation service quality, or recommends ways in which sanitation service quality should be assessed, then this should be done in ways that fully explore and disaggregate possible differences in sanitation service quality as experienced by women and girls and by men and boys; again, specific requirements of women and girls should be given due attention.

iii) If this research in any way uses or promotes some form of community consultation or expert consultation, then this should be done in ways that ensure that women's voices are heard as loudly as men's.

iv) More generally, researchers should interrogate their designs to consider gender implications in all respects and at all levels: for example, a WTP study might (or might not) find it relevant and useful to explore whether WTP differs between women and men; an organisational capacity study might (or might not) wish to explore whether women are represented in high-level decision-making. Again, we stress that we do not require tick-box "inclusion of gender" in all projects; rather, we require that bidders give serious thought to possible gender implications, and include gender-disaggregational elements or other gender-related considerations in their design and analysis where this is important to exploration of the primary research question/s.

QUESTIONS YOU NEED TO ANSWER: In what ways are gender considerations relevant to your proposed design, analysis and research-into-policy work? If you have included gender-disaggregational elements or other gender-related elements in your design, please briefly list these elements.

write here, maximum 150 words (please adhere strictly to this maximum word count)

Requirement 3: Research-into-policy should be considered a core element

Research-into-policy should be considered a core element at all levels and stages of research design; not an after-thought once the "real research" has been completed. Bidders should demonstrate that they have given serious thought to policy influence and policy translation of their findings: this may include [*among other possible elements*] **a)** appropriate consultation at the start-up phase, to ensure that key actors are "on board", or at least that their needs and attitudes have been meaningfully taken into account; **b)** detailed analysis at the design stage of policy context and policy-influence aims and challenges, with consideration of relevant specific aspects such as "windows of opportunity"; **c)** detailed analysis of how in-country actors might need to be involved in the research and/or its subsequent dissemination, in order to maximise chances of policy influence outcomes; **d)** due consideration of dissemination of methods and findings throughout the project, not just at the end; and **e)** inclusion within the team of individuals with specific responsibility for editing to ensure high-quality text. Larger projects may choose to include individuals with specific responsibility for policy translation. We note that WSUP Research & Policy Leads in each of the research countries will expect to be closely involved in research-into-policy work, and you can depend on some support in this area: this can reasonably include WSUP responsibility for preparation of non-academic publication materials summarising key aspects of aims, methodology and eventual findings. [*Here we draw attention to Section 8.2, which states i) that any workshop events included within your bid must be fully funded from your budget, but ii) that WSUP will consider requests over and above budget to cover the costs of open-access academic publication.*]

QUESTION YOU NEED TO ANSWER: In what ways does this project ensure a pro-active research-into-policy focus?

write here, maximum 150 words (please adhere strictly to this maximum word count)

Please submit a completed copy of this form attached as a separate file to you bid.