Editor's comments

Dear authors,
After some difficulties in finding suitable reviewers, your original submission was evaluated by two experts who provided constructive comments and suggestions during the discussion phase of the journal. They also raised some concerns about a few aspects of your paper. The authors' preliminary responses were adequate.
There are some slight differences of opinion between the two reviewers regarding the scientific significance of your study and its quality, most likely due to their different scientific backgrounds. Anyhow, I suggest the authors should improve the revised paper by properly highlighting the contributions your study makes to the current state-of-the-art in this field. Doing so will also enhance the overall quality of the revised article, I guess.

Thank you for the very important suggestion. We modified the Introduction section in the part of the objective formulation as:

"*The overarching objective of this work was to advance the current understanding of microbial contamination in cattle ponds by integrating watershed-scale hydrological modelling, field monitoring of E. coli concentrations, and observational quantification of cattle presence in the pond. We aim4ed to develop a modelling framework that would explicitly represent both hydrologic transport pathways and direct microbial loading by livestock, providing new insight into the dominant mechanisms controlling microbial water quality in agricultural ponds. The specific objectives of this work were to (a) carry out spatiotemporal monitoring of the E. coli concentrations in a typical farm pond in Georgia where cattle grazed on the surrounding land had uninterrupted access to water to drink and cool off; (b) monitor and quantify the presence of cattle in the pond, and (c) develop an E. coli fate and transport hydrologic model that would include transport of manure borne E. coli to the pond, direct deposition of animal waste to the pond, and mixing within the pond*."

We also presented the information on the novelty of the work in the end of the discussion section as: "This study contributes to the current state-of-the-art in several ways. First, it applies a fully mechanistic three-dimensional surface–subsurface hydrological model to simulate microbial fate and transport in and around a cattle pond. Unlike many previous studies that rely on simplified or lumped representations of microbial transport, the present approach explicitly resolves hydrological processes controlling bacterial transport through surface runoff and subsurface flow pathways at the watershed scale. Second, the model explicitly accounts for direct microbial loading caused by cattle entering the pond and depositing manure in the water. The magnitude of this source term was estimated from the observed presence of cattle in the pond using time-lapse imagery obtained from multiple trail cameras. To our knowledge, such direct observational quantification of livestock behavior has rarely been incorporated into mechanistic watershed-scale microbial transport models. Third, the study evaluates the ability of a mechanistic model to reproduce observed E. coli dynamics with minimal calibration using *primarily literature-based parameter values. This approach addresses a common limitation in agricultural water quality studies, where extensive datasets required for model calibration are rarely available. Finally, the modeling framework provides quantitative insight into the relative importance of different contamination pathways, including surface runoff from manure deposited on pasture and direct microbial loading by cattle entering the pond. The results demonstrate that direct excretion by cattle in the pond can dominate microbial inputs under certain management conditions. Overall, this work demonstrates how mechanistic watershed-scale modeling combined with observational data on livestock behavior can be used to improve understanding and prediction of microbial contamination in agricultural ponds."*

We added a reference on pond E. coli modeling to the Introduction section to show that no mechanistic modeling was previously done of the fate and transport both in and around ponds: "Stocker et al. (2020) utilized the EFDC software to simulate the fate and transport of E/ coli in irrigation pond during the water extraction. These authors did not account for sources of microbial contamination around the pond."

Finally, we changed the concluding part of the Abstract stating that "The results demonstrate that mechanistic watershed-scale modeling combined with observational data on cattle behavior can provide useful predictions of microbial contamination in cattle ponds using only readily available data."

Response to Reviewer 1's Comments (assessed by the Editor as an adequate).

The paper entitled "Modeling E. coli fate and transport in and around a cattle pond" deals with pond water contamination by cattle. The authors developed and tested a mechanistic numerical model to simulate watershed-scale surface/subsurface water flow, bacteria release from cow manure, and their fate, as well as transport to a cattle pond. The paper is generally well written but need some clarifications as listed below.

Thank you for your detailed and constructive feedback on our manuscript. We greatly value the reviewer's suggestions, as they highlight important opportunities to strengthen the presentation and interpretation of our results.

My main comment is about the consideration of suspended sediment in the model. As bacteria are mostly transported with eroded soil and manure particles, and as it can survive longer in the sediment, I would expect a more thorough discussion on bacteria and sediment. It is not clear to me (1) how the authors considered the effect of sediment and bacteria resuspension by, e.g., cattle trampling, on bacteria concentration in water, and how they simulated soil and manure erosion along with suspended sediment settling and resuspension, and (2) if the authors considered different die-off rates for water column, soil, and pond sediment.

(1) *We thank the reviewer for raising this important point.*

We agree that sediment-associated bacteria and mechanical resuspension (e.g., cattle trampling) can significantly influence in-stream concentrations. However, the present study focuses on dissolved-phase bacterial transport and does not explicitly simulate sediment erosion, settling, or resuspension processes. In the current version of our model, we have not explicitly accounted for sediment erosion and transport processes, nor for the resuspension of bacteria from bed sediments (including potential effects from cattle trampling or other disturbances). The microbial migration component focuses primarily on direct overland transport from manure application sites (e.g., via runoff and attachment/detachment to soil surfaces) and in-stream decay/inactivation processes, without coupling to a dynamic sediment transport. This simplification was made to maintain computational tractability and to align with the primary objectives of integrating the microbial model into the existing general watershed framework, which itself does not include detailed sediment dynamics.

To address the reviewer's concern, we have added:

(a) *a new paragraph to the* ***Mathematical model*** *section (lines 156–159 in the revised manuscript):*

"The present model does not explicitly simulate soil and manure erosion, suspended sediment transport, settling, or resuspension. As a result, bacterial transport is represented primarily through direct runoff and overland flow pathways, without accounting for attachment to or release from suspended or bed sediments. However, the model accounts for the release of bacteria from cowpats uploaded onto the soil surface."

(b) *A new paragraph to the* ***Discussion*** *section (lines 439–445 in the revised manuscript) explicitly acknowledging this limitation:*

"The present model does not incorporate explicit simulation of soil and manure erosion, suspended sediment transport, settling, or resuspension processes. This omission may underestimate bacterial concentrations in receiving waters during high-flow events, where sediment resuspension, potentially exacerbated by cattle trampling or other disturbances, can act as an important secondary source of fecal indicator bacteria. Numerous studies have highlighted the significance of sediment-associated bacterial transport and resuspension in agricultural watersheds (e.g., Jamieson et al., 2005; Pandey et al., 2012; Bradshaw et al., 2021). Future model extensions could benefit from coupling a sediment transport sub-module to more comprehensively capture these interactions."

We believe this addition provides transparent acknowledgment of the limitation, places our modelling choices in context, and highlights avenues for future improvement without overclaiming the current model's capabilities.

(2) *We considered different die-off rates for the water column and soil, as shown in Tables 1 and 2. The pond sediment die-off rate was assumed to be the same as that for the soil.*

1. L52 “postharvest processing” not clear

We changed it to “habitats for wildlife”.

2. L70 “so the scope of the problem is not well known” not clear

We deleted this from the text.

3. L248-249 This sounds more like method

We prefer to keep it here because “grassland area of around 60000 m^2*” is used in the following calculations*.

4. L256 “each year” as fare as I understand, only 1 winter period was monitored, not clear

We deleted “each year” *from the text.*

5. L261 a verb is missing

The statement was rephrased: “The influx of source terms representing *E. coli* loading from direct cattle excretion into the pond was calculated as described in Section 2.4.3.”

6. L274 “keep the pond from emptying” not clear

We have revised the relevant section of the manuscript to improve precision and readability. Specifically, we replaced the unclear phrasing and added the following explanatory paragraph (lines 287–292 in the revised manuscript):

"The simulated water level in the pond is controlled by a balance of inflows (precipitation and overland runoff) and outflows (evaporation, infiltration through the pond bottom and dam, and any overflow during high-precipitation events). To ensure realistic pond persistence during the multi-year simulation period—preventing unrealistic complete drying while avoiding excessive overflow, we fitted the hydraulic conductivity of the clay liner at the pond bottom to a value of 0.0002 m/day. Increasing this parameter above 0.0002 m/day resulted in excessive seepage losses, leading to a significant and unrealistic decline in the simulated pond water level over the simulation period, which was inconsistent with observed or expected pond behaviour in the study area."

This revision mor clearly explains the role of the hydraulic conductivity parameter in maintaining a stable pond water balance without implying an artificial constraint unrelated to physical processes. The value of 0.0002 m/day (equivalent to approximately 2×10^{-9} m/s) falls within a realistic range for compacted or amended clay liners used in agricultural ponds or waste storage facilities, where low seepage is desired to retain water while allowing minimal infiltration.

7. L278 “Simulations show that it usually occurs during and after rain events” What does the authors mean? Surface runoff occurring during and after rainfall events is rather obvious. The number of days with rainfall was small? Some rainfall events do not generate surface runoff in the catchment, depending on rainfall typology and soil antecedent conditions?

We removed this statement from the text. Also, see our response to the following comment 8.

We also explained a small but persistent surface water inflow to the pond during dry periods (lines 305-309): “This small but persistent surface water inflow to the pond during dry periods (no precipitation), attributable to slow drainage of shallow subsurface lateral flow (interflow or return flow) from upslope areas that daylights and reaches the pond via surface pathways. This is distinct from precipitation-driven overland flow/surface runoff, which occurs only during or immediately following rainfall events (Tarboton, 2003).”

8. L285-296 does it mean that, in the model, surface runoff also occurs when there is no rain? Do the authors call “runoff” the surface runoff or the overall water yield to the pond? Besides, is the dam completely impervious?

No, the model does not generate surface runoff during periods without precipitation.

In the manuscript (lines 297–300), we explain what we refer to as runoff: “The HGS model calculates fluid fluxes across the pond boundary. Water fluxes are computed between active nodes (located on the pond boundary—dark blue dots in Figure 3a) and contributing nodes (located just outside the pond boundary). The calculated surface water flux represents the simulated runoff to the pond (Figure 7).”

In the simulations, the dam is build of clay with the hydraulic conductivity of 0.0002 m/day (lines 226-227).

9. L318 “Concentration in the pond source locations” is it what the authors call “interior locations” on L365?

Changed to “Concentration in the source locations, simulating cattle excretion in the pond (Figure 3a),”

10. L324-325 What was the sampling protocol regarding the presence of cows in the pond or on the shores at sampling time? Were some samples taken in the vicinity of a cow that would resuspend sediment by trampling and mixing water?

We added the following statement (lines 131-132 of the revised manuscript: “All samples were taken between 10:00 and 12:00 in the absence of cows.”

11. L337, 338, 339 “shoulder” not clear. On L339, the point in “After the "shoulder" period. The” must be revised.

We changed the jargon term “shoulder” *to the commonly used* “lag period.”

12. L355 “entering the pond by manure excretion” do the authors mean “by direct excretion of feces into the pond”, as suggested in L359? I would suggest a similar revision of the sentence on L420-421.

Corrected following the reviewer's comment.

13. L356-357 If I understand well the meaning, I would rephrase as such: “Simulations show that water flowed mainly from the pond into the subsoil, so that E. coli concentrations in the subsoil did not affect the water quality in the pond.”

Rephrased as suggested by the reviewer.

14. L359, 363 remove capital C to “Coli”

Removed.

15. L368-373 what about the role of temperature?

While the effect of temperature was not explicitly studied, it was accounted for in the simulations by introducing a temperature-dependent E. coli die-off rate (lines 237-240).

Response to Reviewer 2’s Comments (assessed by the Editor as an adequate).

Comment

The manuscript coded and entitled “egusphere-2025-4138. Modeling E. coli fate and transport in and around a cattle pond” presents interesting results about E. coli inputs and concentrations inside a cattle pond during a 15-month period. The overall presentation is well structured and clear. Methodologies for characterizing the inputs and concentrations are sufficiently described. The number of data and measurements of inputs are adequate.

However, the part regarding mathematical modelling could be significantly improved. The authors could conduct a more in-depth literature review to obtain die-off rate values from other references and better fit their value, taking into account a broader bibliographic range. Then they could calibrate their model (presented currently as non-calibrated). Performing a sensitivity analysis of the model to the different parameters included in the equations (tables 1 and 2) is recommended. This sensitivity analysis provides a better understanding of the system behaviour. In addition, authors may wish to consider including more removal processes and comparing the goodness of fit considering a single process (current version) or several (improved version to better understand the functioning of the ecosystem). Considering more processes helps to improve understanding of how the system works and even to be able to make recommendations to promote greater removal of bacteria in the pond.

Response

Thank you for your detailed and constructive feedback on the mathematical modeling aspects of our manuscript. We greatly value the reviewer's suggestions, as they highlight important opportunities to strengthen the presentation and interpretation of our results.

We fully agree that an expanded literature review on bacterial die-off rates, model calibration, sensitivity analysis, and the inclusion of additional removal processes (e.g., sedimentation, filtration, predation, or UV inactivation in pond systems) would provide deeper insights into fecal indicator bacteria dynamics in manure-impacted systems. Similarly, performing calibration against site-specific observations, conducting formal sensitivity analyses (e.g., using methods such as Latin-Hypercube One-at-a-Time or global approaches), and comparing single- versus multi-process formulations would offer valuable understanding of key controlling factors and potential management implications for improving bacterial removal in ponds or similar ecosystems.

However, the primary objectives of the present study were focused on the conceptual integration of the microbial migration model into the existing general watershed modeling framework and accounting for the microbial water quality in the cattle pond, with an emphasis on demonstrating the feasibility of this coupling, basic process representation, and qualitative evaluation of simulated microbial fate under representative scenarios. As such, formal model calibration against field measurements, detailed sensitivity analyses of the parameters in Tables 1 and 2, and systematic comparison of alternative removal process formulations were not among the aims of this research phase. The die-off rate employed was selected based on representative values from the literature applicable to similar agricultural settings (with appropriate citation), while keeping the model parsimonious to facilitate initial testing and integration.

To address the reviewer's recommendations transparently, we have revised the manuscript as follows:

> In the **Methods** section (around lines 238–245), we have expanded the justification for the chosen die-off rate by referencing published datasets:

"E. coli die-off/inactivation rates exhibit considerable variability depending on environmental conditions, e.g., temperature, moisture, pH, organic matter content, attachment to particles, solar radiation, predation, and matrix type such as manure, soil, runoff, or pond water (Lim and Flint, 1989; Soupir, 2007; Ravva and Korn, 2007; Muirhead, and Littlejohn, 2009; Oliver et al., 2010; Tran et al., 2020). The E. coli die-off parameters in Table 1 and 2 were taken as average over the parameters for datasets presented in published databases. The Q10 model parameters of E. coli survival in water were averages over 16 survivals in wastewater datasets presented in the work of Blaustein et al (2013), and the Q10 model parameters of E. coli survival in manure were averages over seven experimental datasets with bovine manure published by Martinez et al. (2013).”

In the **Discussion** sections (new paragraph, lines 446–454), we have explicitly acknowledged the absence of calibration and sensitivity analysis:

"The current implementation does not include site-specific calibration or formal sensitivity analysis of key parameters (e.g., die-off rates, sorption coefficients as listed in Tables 1 and 2). While these steps would provide valuable insights into parameter influence and model behavior—and are recommended for future applications, the present work prioritizes proof-of-concept integration and qualitative assessment over quantitative optimization. Similarly, the model currently incorporates a single dominant removal process (first-order die-off/inactivation) to maintain simplicity during initial coupling; additional mechanisms (e.g., settling, resuspension, or biotic interactions) were not included but represent promising extensions. Such enhancements could better elucidate ecosystem functioning and inform management strategies to enhance bacterial removal in pond systems, as supported by prior modeling efforts in watershed-scale microbial fate and transport (e.g., Ferguson et al., 2010; Bradford et al., 2013; Cho et al., 2016)."

These additions aim to provide a clearer context for our modeling choices, recognize the limitations constructively, and position the work as a foundation for more advanced analyses in subsequent research.

Comments on formal aspects:

1. Line 14: the aim of this work is (verb is missing).

Response

Corrected.

Comment

2. Line 17-18: The complete name Escherichia coli should be placed the first time the abbreviation appears in line 17.

Response

Corrected.

3. Line 338-339. The sentence is cut by a dot.

Corrected.

Comment

4. References are not alphabetically ordered and some of them are cut, making their search difficult.
5. Response

Following your comment, we reviewed the references and arranged them alphabetically.