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# Maternal water sanitation and hygiene (WASH) related risk factors for Point of Use (PoU) drinking water quality in communities with improved water supply & sanitation facility

## Abstract

The effect of improved water supply and sanitation infrastructure on health may have minimal effects after certain level of saturation in facilities. Nepal recently achieved South Asian Conference on Sanitation (SACOSAN) goal but diarrhoea still is common cause for under-five mortality. Assessing if improved facilities are safe at the consumption level for health benefits is important. A cross sectional study was performed with 627 mothers (Salyan=324 & Humla=303) in two rural districts of Nepal to understand main effect of five operational compliances for Point of Use (PoU) drinking water microbial safety. Despite of improved water supply in 93.6% of households, 184 (29.3%) PoU water was *E.coli* contaminated. About 12.6% households reported of having at least one ill family member during the time of survey, in which diarrhoea (51.9%) was common. PoU water from improved supply is not safe at consumption level. Considering only improved facilities alone is not sufficient for health benefits. Household Water treatment and safe storage behavior have shown to be significant in maintaining microbial quality at PoU level.

**Keywords:** Point of use, *E.coli*, improved water supply, improved sanitation, HWTS

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## Introduction

Access to improved water supply may not always ensure safety at consumption level.[1,2] Microbiological contamination risk in drinking water increases during collection and storage at home.[3–6] Allied Water Sanitation and Hygiene (WASH) factors influences microbiological contamination at Point of Use ( PoU) drinking water.[1,7] Consumption of contaminated water is the main predictive cause for diarrheal incidence.[8] The effect of improved water supply and sanitation infrastructure on health may have minimal effects after certain level of saturation of facilities. Sufficient quantities of clean water by itself will not reduce the incidence of water related diseases, especially among children, the most vulnerable group.[9] Nepal recently achieved South Asian Conference on Sanitation (SACOSAN) goal for improved water supply and sanitation coverage and diarrhoea still is common cause for under-five mortality. Assessing if improved facilities are safe at the consumption level for health benefits is important. As the drinking water contamination risk increases after collection and storage, understanding consumption level maternal Water Sanitation and Hygiene (WASH) compliances can aid for microbial safety of drinking water which may eventually limit diarrheal incidence among under-five children.

## Methods

A cross sectional study was performed with 627 mothers (Salyan=324 & Humla=303) in two rural districts of Nepal. Sample size was estimated using prevalence formula [$N=4(PQ)/L^2$] with 5% allowable error and 95% confidence interval. Geometric mean of those indicators which may affect water safety were considered for calculation. Indicators considered were: (i) improved water supply coverage, (ii) sanitation coverage, (iii) improved drinking water source, (iv) water treatment practice, (v) use of improved sanitation by community, (vi) safe disposal of child's excreta, and (vii) soap-water availability in hand washing facility. A random starting point was selected and every third house was approached for participation. The inclusion criteria was: (i) at least one under five children in household (HH), (ii) female respondent (preferably mother) above 18 years, (iii) provide 125ml of PoU drinking water for microbial analysis. Adjacent HH was approached if the criteria were not met.[10] Mothers were purposively selected, as being directly involved in household chores with good knowledge of domestic water, sanitation, and hygiene practices.[8] Potential covariates affecting microbial safety were assessed. Questionnaire survey and spot observations was done to assess WASH compliances. An operational pictorial show card was used to reduce observational bias.

PoU drinking water samples from those utensils from which water would have been consumed (6) was collected and immediately transported (less than 6 hours) to onsite laboratory. Membrane filtration method was considered following American Public Health Associations 1998 guidelines. *Escherichia coli* (*E.coli)* were incubated in wag-tech field test kits to assess microbial safety. Dichotomous variable of *E.coli* contamination was created to assess possible associations. Five operational compliances - (i) HH WASH status, (ii) HH environment, (iii) Maternal education, (iv) Maternal WASH behavior, and (v) HH water treatment and safe storage (HWTS) was assessed for microbial safety with potential covariates (Table 2). Mothers were also asked to provide binary recall of diarrheal incidence for her and all family members at the study duration & seven days prior interview date. Operational compliances was considered as safe, or clean, or aware, if all assumed covariates were reported or observed to be in/directly protective against microbial contamination. Chi-square, odds ratio, and binary logistic regression were performed to understand main effect of compliances for microbial safety. Households were informed about their water

quality at the end of study. Lab results were further shared with Mala IV program (integrated maternal child health program) in study site for needful program activities to ensure microbial safety of the area.

# Results

## Respondent and household characteristics

Kuppuswamy's Socio-Economic Status (SES) scale[11] was further contextually tailored, where lower and upper lower class was merged to "Lower class", lower middle & upper middle to "Middle class", and upper middle & upper to "Upper class". Middle class households was common (63.6%) with mothers aged 26 years (SD=5years) and 28 months (SD=14months) of under five children. Mothers were literate (82.3%) and affiliated (70.3%) in at -least one community level health or sanitation group or both. Drinking water supply was from improved source for almost all (93.6%) households and 93.8% of households had permanent sanitation facility.

## Health status

About 12.6% households reported of having at least one ill member during the time of survey, in which diarrhoea (51.9%) was commonly reported. Ill under five year's children prior seven days of survey was reported by 11.3% households. Diarrhoea was again most common (38%), followed by fever and diarrhoea combined (11.3%), persistent diarrhoea (9.9%), and fever alone (9.9%).

## PoU water quality

Despite of improved water supply in 93.6% of households, 184 (29.3%) PoU drinking water was *E.coli* contaminated. Bacteriological Risk grading (7) among contaminated samples (n=184) revealed that 50% were in low risk (1-10 cfu/100ml), 26.6% in very high risk (101-1000 cfu/100ml), and 23.4% in high risk (11-100 cfu/100ml). Contamination was same regardless to SES category.

## Maternal behavior

Drinking water treatment was practiced by 18% of households in which 35.4% were practicing unsafe method. Almost all (92.3%) reported to use soap and water for hand washing and 71.9% reported to safely dispose children's excreta. Majority (82.6%) of mothers reported to practice safe actions in child diarrhoea (Table 1).

# Operational compliances and microbial safety

## Household wash status

Unlike other studies,[6,12] the odds of contamination for improved supply is 32% higher in study sample. HHs with no permanent sanitation facility had twice much odds of PoU water contamination. The odds of PoU water contamination to those HHs with no hand washing facility for sanitation is 3 times higher than that of HHs with hand washing facility for sanitation. Hand washing facility in kitchen, and stock soap availability in household showed no significant association with PoU water quality (Table 2). Compliance defining household's WASH status had no any significance in PoU drinking water quality (Table 3), and health status of household member.

## Household environment

The odds of *E.coli* contaminated PoU drinking water is thrice much higher in households with unclean sanitation facilities. Unclean houses i.e. presence of animal or human excreta in compound, showed no any significance on same. Presence of stagnant water around household's posses 63% higher odds of being PoU water contaminated (Table 2). Compliance defining household environment revealed that unclean environment attributes 51% greater odds for PoU contamination but is not significant for health status of family member in study population (Table 3).

**Table 1** General characteristics of household

| Sampled household characteristics | N=627 (%) | Sampled household characteristics | N=627 (%) |
|---|---|---|---|
| Drinking Water Type | | Current Health Status | |
| Improved Supply | 587 (93.6%) | HH with Ill Member | 79 (12.6%) |
| Un Improved Supply | 40 (6.4%) | Healthy HHs | 548 (87.4%) |
| PoU E.coli contamination | | HH with Ill Children prior 7 days | |
| Uncontaminated | 443 (70.7%) | Yes | 71 (11.3%) |
| Contaminated | 184 (29.3%) | No | 556 (88.7%) |
| Sanitation in HH | | Children's Illness (n=71) | |
| Yes | 588 (93.8%) | Diarrhoea | 27 (38.0%) |
| No | 39 (6.2%) | Fever & diarrhoea | 8 (11.3%) |
| Current HH Illness (n=79) | | Persistent diarrhoea 7 (9.9%) | |
| Diarrhoea | 41 (51.9%) | Fever | 7 (9.9%) |
| Fever | 14 (17.6%) | Fever & Cough | 6 (8.5%) |
| Common cold & fever | 10 (12.7%) | Fever, diarrhoea & Cough | 4 (5.6%) |
| Other chronic disease | 7 (8.9%) | Blood in diarrhoea | 4 (5.6%) |
| Pneumonia | 6 (7.6%) | Pneumonia | 3 (4.2%) |
| Fever & diarrhoea | 1 (1.3%) | Cough | 3 (4.2%) |
| | | Others | 2 (2.8%) |

**Table 2** Factors associated with *E.coli* contamination

| Household's wash status | E.coli contamination | | Total (N=627) | $\chi 2$ (P) | OR(CI) |
|---|---|---|---|---|---|
| | -ve (n=443) | +ve(n=184) | | | |
| Drinking Water Supply | | | | | |
| Improved | 69.5% (408) | 30.5% (179) | 100% (587) | 5.848(0.016) | 0.326((0.126 to 0.845)) |
| Unimproved | 87.5% (35) | 12.5% (5) | 100% (40) | | |
| Permanent Sanitation | | | | | |
| Yes | 73.0% (412) | 27.0% (152) | 100% (564) | 15.538 | 2.798(1.651 to 4.743) |
| No | 49.2% (31) | 50.8% (32) | 100% (63) | 0 | |
| Hand washing facility in Kitchen | | | | | |
| Yes | 70.2% (184) | 29.8% (78) | 100% (262) | 0.39 | - |
| No | 71.0% (259) | 29.0% (106) | 100% (365) | -0.843 | |
| Hand washing facility in Toilet | | | | | |
| Yes | 85.7% (198) | 14.3% (33) | 100% (231) | 40.010(0.000) | 3.698(2.428 to 5.632) |
| No | 61.9% (245) | 38.1% (151) | 100% (396) | | |
| Stock soap in HH | | | | | |
| Yes | 71.7% (198) | 28.3% (78) | 100% (276) | 0.280(0.597) | - |
| No | 69.8% (245) | 30.2% (106) | 100% (351) | | |
| Household's environment | | | | | |
| Stagnant water in HH | | | | | |
| Yes | 62.2% (61) | 37.8% (37) | 100% (98) | 3.961(0.047) | 0.634(0.404 to 0.996) |
| No | 72.2% (382) | 27.8% (147) | 100% (529) | | |
| Clean HH | | | | | |
| Yes | 74.6% (194) | 25.4% (66) | 100% (260) | 3.362(0.067) | - |
| No | 67.8% (249) | 32.2% (118) | 100% (367) | | |
| Clean Toilet | | | | | |
| Yes | 76.7% (371) | 23.3% (113) | 100% (484) | 35.834((0.000)) | 3.238(2.193 to 4.780) |
| No | 50.3% (72) | 49.7% (71) | 100% (143) | | |
| Maternal knowledge | | | | | |
| Mother's Education | | | | | |
| Educated | 73.1% (377) | 26.9% (139) | 100% (516) | 8.152(0.004) | 1.849((1.208 to 2.831)) |
| Illiterate | 59.5% (66) | 40.5% (45) | 100% (111) | | |
| Mother Affiliated | | | | | |
| Yes | 63.0% (278) | 37.0% (163) | 100% (441) | 41.580(0.000) | 0.217(0.133 to 0.356) |
| No | 88.7% (165) | 11.3% (21) | 100% (186) | | |
| Maternal knowledge contd... | | | | | |
| Heard of Safe Motherhood | | | | | |
| Yes | 72.1% (194) | 27.9% (75) | 100% (269) | 0.488(0.485) | - |
| No | 69.6% (249) | 30.4% (109) | 100% (358) | | |
| Correct ANC Knowledge** | | | | | |
| Yes | 72.9% (258) | 27.1% (96) | 100% (354) | 1.784(0.182) | - |
| No | 67.1% (106) | 32.9% (52) | 100% (158) | | |
| Correct PNC Knowledge** | | | | | |
| Yes | 80.6% (87) | 19.4% (21) | 100% (108) | 2.744(0.098) | - |
| No | 71.2% (89) | 28.8% (36) | 100% (125) | | |

Table Continued...

| Household's wash status | E.coli contamination | | Total (N=627) | $\chi^2$ (P) | OR(CI) |
|---|---|---|---|---|---|
| | -ve (n=443) | +ve(n=184) | | | |
| Maternal Opinion Fluids in Diarrhoea | | | | | |
| Correct Opinion | 69.6% (314) | 30.4% (137) | 100% (451) | 0.823(0.364) | - |
| Incorrect Opinion | 73.3% (129) | 26.7% (47) | 100% (176) | | |
| Maternal Opinion for Hand wash | | | | | |
| Soap & Water | 72.3% (421) | 27.7% (161) | 100% (582) | 11.076(0.001) | 2.734(1.482 to 5.042) |
| Others | 48.9% (22) | 51.1% (23) | 100% (45) | | |
| HWTS | | | | | |
| Storage of Drinking water | | | | | |
| Covered | 72.0% (413) | 28.0% (161) | 100% (574) | 5.512(0.019) | 1.967(1.109 to 3.488) |
| Uncovered | 56.6% (30) | 43.4% (23) | 100% (53) | | |
| Clean Storage Vessel | | | | | |
| Yes | 70.8% (435) | 29.2% (179) | 100% (614) | (0.539)* | - |
| No | 61.5% (8) | 38.5% (5) | 100% (13) | | |
| Treat drinking water | | | | | |
| Yes | 91.2% (103) | 8.8% (10) | 100% (113) | 27.929(0.000) | 5.271(2.685 to 10.347) |
| No | 66.1% (340) | 33.9% (174) | 100% (514) | 0 | |

**Table 3** Operational compliances associated with *E.coli* contamination

| Compliances | | *E.coli* contamination | | $\chi^2$ (P) | OR (CI) | Family health | | $\chi^2$ (P) | OR (CI) |
|---|---|---|---|---|---|---|---|---|---|
| | | -ve (n=443) | +ve (n=184) | | | ILL(n=79) | Healthy (n=548) | | |
| WASH Status | Unsafe | 69.8% (391) | 30.2% (169) | 1.752 (0.186) | - | 12.3%(69) | 87.7% (491) | 0.368 (0.544) | - |
| | Safe | 77.6% (52) | 22.4% (15) | | | 14.9%(10) | 85.1%(57) | | |
| Household Environment | Unclean | 67.0% (301) | 33.0% (148) | 9.974 (0.002) | 0.516 (0.340 to 0.781) | 12.7%(57) | 87.3% (392) | 0.013 (0.909) | - |
| | Clean | 79.8% (142) | 20.2% (36) | | | 12.4%(22) | 87.6% (156) | | |
| Maternal Knowledge | Unknowledgeable | 70.4% (340) | 29.6% (143) | 0.069 (0.793) | - | 14.1%(68) | 85.9% (415) | 4.177 (0.041) | 1.981 (1.018 to 3.857) |
| | Knowledgeable | 71.5% (103) | 28.5% (41) | | | 7.6%(11) | 92.4% (133) | | |
| Maternal WASH Behavior | Unsafe | 70.3% (426) | 29.7% (180) | (0.341)* | - | 12.7%(77) | 87.3% (529) | 0.187 (0.666) | - |
| | Safe | 81.0% (17) | 19.0% (4) | | | 9.5%(2) | 90.5%(19) | | |
| HWTS | Unsafe | 66.2% (341) | 33.8% (174) | 27.416 (0.000) | 0.192 (0.098 to 0.377) | 12.4%(64) | 87.6% (451) | 0.078 (0.780) | - |
| | Safe | 91.1% (102) | 8.9% (10) | | | 13.4%(15) | 86.6%(97) | | |

*Fisher's Exact
HWTS- Household Water Treatment & Storage

## Maternal knowledge

The odds of PoU contamination were 1.849 times greater in those household's with illiterate mothers. Mother's affiliation to any of community groups (community based health and/or WASH group) tends to decreases PoU Contamination risk by odds of 21%. Mothers who did not opted for soap & water for hand washing have 2.73 times higher odds for PoU contamination. Maternal awareness on safe motherhood, and amount of fluids to be given in diarrheal condition showed no any significance with PoU contamination (Table 2). Maternal knowledge compliance was not significant for PoU contamination in study population (Table 3). However, ill

household member in those households with unknowledgeable mothers was significantly high (OR=1.981, CI=1.018-3.857, P<0.05). 11 households with knowledgeable mothers had at-least one family member ill during survey, while the number of same was 68 in households with unknowledgeable mothers.

### Maternal wash behavior

Three times higher odds of PoU contamination were observed in those households where mothers do not use soap & water for hand washing. Hand washing after cleaning child's bottom and before cooking is safer for microbial quality of PoU drinking water by odds of three times & 55% respectively. Safe excreta disposal of under five children, hand washing practice after defecation & before eating showed no significance in PoU contamination for study sample (Table 2). Compliance defining maternal WASH behavior did not showed any significant in PoU drinking water quality and health status of family members in study population (Table 3).

### Household water treatment and safe storage (HWTS)

Those mothers reporting to not treat their drinking water possessed five times higher odds for PoU drinking water contamination. Similarly, uncovered water storage vessels possess 1.967 times higher odds for contamination. Cleaning of storage vessels did not showed any significance for contamination in study sample (Table 2). HWTS compliance showed that unsafe HWTS possessed 19% higher odds for PoU contamination (Table 3), while the compliance had no significance for health status.

All operational compliances were analyzed in binary logistic for *E.coli* contamination. Except HWTS, all other compliances were non-significant (Table 4). Though the pseudo R-square (Nagelkerker R square=0.079) was weak, non-significant Hosmer and Lemeshow test (0.834) signifies model fitness for analysis with 70.7% of predictive capacity. Safe HWTS increases the log it of estimated log odds for uncontaminated PoU drinking water by 1.580 units. Those who tend to have safe HWTS are more likely to have uncontaminated PoU drinking water by odds of 20% (CI=0.101 to 0.421). Clean household environment is also commendable for PoU drinking water safety with weaker statistical significance (Table 4). Again, all compliances were tested for family health status in binary logistic to gauze what compliance may have effect on family health. With weak pseudo R-square (Nagelkerker R square=0.015) and non significant Hosmer and Lemeshow test (0.969), analysis revealed that knowledgeable mothers increases the log it of estimated log odds for healthy family members by 0.680 units. Knowledgeable mothers are more likely to have healthy family members by odds of 1.973 times (CI=0.999-3.896).

**Table 4** Binary logistic regression for operational compliances and *E.coli* contamination

| Variables in the equation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | B | S.E. | Wald | df | Sig. | Exp(B) | 95% C.I.for EXP(B) | |
| | | | | | | | | Lower | Upper |
| Step 1a | WASH STATUS | 0.233 | 0.366 | 0.405 | 1 | 0.524 | 1.262 | 0.616 | 2.584 |
| | HH ENVIRONMENT | -0.434 | 0.254 | 2.921 | 1 | 0.087 | 0.648 | 0.394 | 1.066 |
| | Maternal KNOWLEDGE | 0.054 | 0.221 | 0.059 | 1 | 0.809 | 1.055 | 0.684 | 1.628 |
| | Maternal WASH BEHAV | 0.379 | 0.627 | 0.366 | 1 | 0.545 | 1.461 | 0.428 | 4.996 |
| | HWTS | -1.58 | 0.364 | 18.814 | 1 | 0 | 0.206 | 0.101 | 0.421 |
| | Constant | -0.618 | 0.112 | 30.511 | 1 | 0 | 0.539 | | |

a. Variable(s) entered on step 1: WASH STATUS, HH ENVIRONMENT, Maternal KNOWLEDGE, Maternal WASH BEHAV, HWTS.

## Discussion

Almost half of the PoU drinking water was contaminated however, no directly associated with diarrheal disease was recorded. Assumed variance in compliances assesses several important risk factors.[10,12–14] The set of operational compliances considered overall hardware and software components of WASH which could affect PoU water quality. This allowed in reducing biases for not considering unobserved probable factors. Compliances were only considered to be "Safe", "Clean", and "Aware" when all risk factors were either directly or indirectly protective for PoU contamination. The general purpose of it is to check if feasible multiple barriers would have any association with water quality. In general, findings showed promising results and were comparable with most research findings across the world. Having safe WASH status, clean household environment, maternal WASH behavior, HWTS, and health seeking behavior were evidenced of having less odds of PoU contamination.

Binary logistic model further revealed that HWTS was most significant for contamination. Covered storage vessel contributes in microbial safety at PoU, this finding is similar to other studies.[10,6,13,14] Safe storage is important as treated or safe water stored in unsafe storage will have obvious contamination. Treatment of water prior drinking is universal approach for water safety. Small proportion of households reported to treat water prior drinking. Unlike study findings from Gupta et al., in our study those who reported to treat water have significantly low PoU contamination. The negative contamination to those who reported of treating shows that responded truly reported their household behavior. Unlike other study findings,[6,12] our findings showed that improved supplies were significantly more contaminated. A study by Rai et al. in mountains of Nepal shows similar results where 90.1% piped taps was contaminated. Improved supply alone is not enough where there is prolonged storage of drinking water.[13] Household engages set of complex behavior. Social influences like social norms affect the behavior. Social norms may or may not be stated explicitly but are understood by members of a group without any external input. Similar to finding of Fisher et al., in our study the perception of residents that water from improved supply is clean and need not be treated at home was a common social norm.[8,15] It has

also been evidenced that households with an improved source are percentage points less likely to engage in in-home treatment.[16] These findings relates to theory of reasoned action, which states that person's behavioral intention depends on attitude towards particular behavior and subjective norms. May be the complex dual role of inexplicit social norm is negatively influencing attitude for water treatment.

The theory of planned behavior advances reasoned action theory by considering perceived behavioral control i.e. degree to which person believes that they control any given behavior. The theory further suggests that behavior is likely to be enacted if prospective practitioner feels that they can enact them successfully. In study population where social norm, attitude, are negative towards water treatment practice, considering those safe behaviors which are self efficient and controllable is more convincing. Self efficacy and controllability are two dimensions of perceived behavioral control. Risk factors listed in HWTS compliance in this study could be effective for microbial safety of drinking water at PoU. Compliance factors that are considered in the study are within household capabilities with no external inputs required to practice same. Self efface ability and controllability both are ensured as those behaviors are easily doable by resident's own ability with full control over performance of behavior. High perceived behavioral control increases the confidence of performing specific behavior successfully. The study finding has limited evidence to generalize same leaving scope for further research. We failed to find any statistically significant association to contamination with risk factors like, behavioral - hand washing after defecation, before eating, children's excreta disposal; WASH status - hand washing facility in kitchen, stock soap in resident; and household's environmental - clean storage vessel, stagnant water in resident. Like several other studies,[16,17] no strong associations was evidenced for diarrheal disease and *E.coli* contamination. However, diarrhoea was reported as the most commonly reported disease among adults and under five children in sampled households. Diarrhoea is multi-factorial in origin; hygienic use of safe water is evidenced with health benefits in developing counties.[14] Safe drinking water from improved supply remains a challenge. Generally water treatment options are focused on unimproved supply.[6] It can be even more important to make improved supply safe. Improved supply gives an impression that no additional intervention shall be needed.[15] The perception that improved supply is safe and needs no treatment makes large scale of population vulnerable.

Safety at supply level alone may not be sufficient due to complex behavioral aspects at household level. Microbial safety of PoU drinking water depends on behavioral aspect and other allied factors which influences those behaviors. Treatment of water at end point i.e. PoU has been widely acknowledged to be effective and efficient method.[6,13] Women's involvement in designing drinking water related activities is crucial as women are key players in water collection, storage, handling, and household related hygiene.[18] Maternal knowledge was significant for health status and HWTS for water quality. HWTS has the potential to improve water safety. HWTS practices yield improvements in drinking water quality and reductions in diarrheal disease.[19] Mothers are commonly responsible for HH related WASH chores, which also determine family health in many ways. Knowledge of mothers was commendable in study sample but HWTS was unsafe and water contamination and diarrheal disease was high. Most of them even reported to practice unsafe drinking water treatment practice. Enhancing maternal HWTS behavior may yield health benefit from improved facilities in this concern. It is important to address enablers and barriers of HWTS for its sustainability & scale-up.[19]

## Conclusion

PoU water from improved supply is not safe at consumption level. Considering only improved facilities alone is not sufficient for health benefit. Unsafe improved supply exaggerates vulnerability and may create false perception affecting possible precautionary behavior for water safety. Not just improved, but safety is important. Water treatment and safe storage behavior have shown to be significant in maintaining microbial quality at PoU level. Focus on enhancing maternal knowledge on HWTS is important for safe water and health benefits. Studies exploring behavioral change theory for household's HWTS can shade more light for safe drinking water at consumption level.

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## Conflicts of interests

Author declares that there is no conflict of interest.

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