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# Fear appeals, individuals' cognitive-behavioral responses, and willingness to pay for safe water in fluoride-contaminated regions

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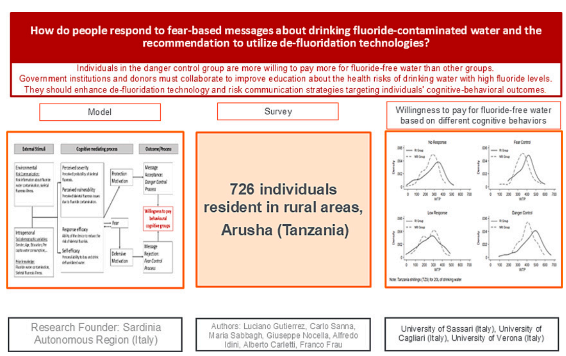
## HIGHLIGHTS

- We explore the impact of fear appeals on promoting protective behaviors and willingness to pay for fluoride-free water.
- Conducted in the Rift Valley of Tanzania, we used the Extended Parallel Process Model in a contingent valuation survey.
- Results show that EPPM components have varying roles depending on health risk perceptions.
- Governmental institutions are crucial to improve education on the health risks of fluoride concentrations in drinking water.

## GRAPHICAL ABSTRACT

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## ABSTRACT

In rural areas with high fluoride concentrations in groundwater, affordable and effective de-fluoridation technologies can significantly reduce the likelihood of being affected by fluorosis-related illnesses, such as skeletal fluorosis. This is particularly significant in areas where groundwater is the primary or sole drinking water source, such as the Rift Valley of Tanzania. Despite the availability of technologies, people's use of de-fluoridation devices still needs to be improved. This study investigates the potential impact of fear appeals on promoting protective behaviors and willingness to pay for fluoride-free water. The fear appeal emphasizes the negative health effects of drinking water with high fluoride levels and suggests using water from a specific de-fluoridation device to reduce the risk of being affected by skeletal fluorosis. To analyze the impact of the fear appeal, we use the Extended Parallel Process Model within a contingent valuation survey conducted in the Rift Valley of Tanzania. Results show that the theoretical components of this model have varying roles in the presence and

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absence of health risk perceptions. Respondents who receive health risk information are more willing to pay for fluoride-free water than other participants and are interested in adopting precautionary behavior. Governmental institutions and donors should collaborate to improve education on the health risks of drinking water with high fluoride concentrations. Additionally, they should work on enhancing de-fluoridation technology and developing effective risk communication strategies, specifically focusing on individuals' cognitive-behavioral outcomes.

## 1. Introduction

Excessive fluoride in drinking water affects about 200 million people, mainly living in rural areas (Akuno et al., 2019; Del Bello, 2020; Kimambo et al., 2019). The World Health Organization recommends a safe limit of 1.5 mg/L of fluoride in drinking or cooking water (WHO, 2011). However, fluoride levels in drinking water above this limit can be found in 24 countries. These countries are mostly located in the "fluoride belts," spanning from Syria to Uganda and Turkey to China (Khairnar et al., 2015; Tekle-Haimanot et al., 2006).

The consumption of drinking water contaminated with fluoride for a prolonged period can lead to dental and skeletal fluorosis. The former causes physical damage to teeth, while the latter can result in joint pain, reduced mobility, and permanent disability (Fawell et al., 2006), which affects the health of people severely and irreversibly because there are currently no standard treatments available (Yang et al., 2017).

Developing cost-effective, sustainable, and user-friendly defluoridation techniques (DTs) could be an important strategy to combat fluorosis diseases. According to many authors, this strategy is considered one of the best ways to treat fluoride-contaminated water in rural areas (Ayoob et al., 2008; Gutierrez et al., 2023; Idini et al., 2020; Nocella et al., 2022; Yadav et al., 2018). However, despite the potential of DTs in providing safer drinking water and reducing the economic and health burden of fluorosis diseases, their adoption remains low. Several studies emphasize that DTs are not widely accepted for different reasons (Burt et al., 2017; Lilje and Mosler, 2017). For example, understanding risk factors that influence people's consumption of safer water could be crucial to enhance public health and encourage the adoption of household drinking water treatment technologies. Technical issues, such as inadequate power supply and shortage of qualified technicians for maintenance, are factors limiting the implementation of innovative technologies in rural areas of developing countries. For instance, despite significant advancements in the effectiveness of different techniques to reduce fluoride content in drinking water, these techniques are more viable among households living in semi-urban and urban areas (Melak et al., 2019; Panagopoulos and Giannika, 2024; Riffat and Husnain, 2022).

One of the strategies used by policymakers and stakeholders to trigger people's protective behavior is the use of fear-inducing messages. They are commonly utilized in health education campaigns because it is assumed that the more individuals are made aware of the potential consequences of their unhealthy behavior, the more likely they are to take the recommended action. Multiple meta-analyses on appealing to fear have supported the idea that strong fear messages are more effective in changing attitudes, intentions, and behaviors than weak fear messages (Boster and Mongeau, 1984; De Hoog et al., 2007; Tannenbaum et al., 2015; Witte and Allen, 2000). These messages are persuasive appeals that evoke fear by emphasizing potential harm if recipients do not follow the recommendations. Various theories have analyzed the impact of fear appeals on behavior: the Health Belief Model (Becker et al., 1978; Rosenstock, 1996; Rosenstock, 1974), the Parallel Process Model (Leventhal, 1970), the Protection Motivation Theory (Rogers, 1983; Rogers and Deckner, 1975), the Extended Parallel Process Model (Witte, 1992, 1994, 1998; Witte et al., 1996).

In light of this introduction, this study explores the impact of health risk messages on rural communities living in the Arusha region of Tanzania, where people's exposure to skeletal fluorosis is significant due to the highest fluoride concentration in Tanzania with an average of 13.57 mg/L. Furthermore, we focus on skeletal fluorosis because this is a severe, progressive, and disabling condition that leads to the deterioration of overall health (Veneri et al., 2023).

In particular, we adopt the Extended Parallel Process Model, a cognitive-behavioral response framework developed by Witte (1992, 1998), where both the threat of being subjected to skeletal fluorosis and the response efficacy of using a new DT system are examined by administering low and high fear appeal messages. The DT system used in the fear appeal messages was approved by the Tanzanian Ministry of Water (Idini et al., 2019; Idini and Frau, 2021), and its utilization can reduce the risk of skeletal fluorosis by supplying fluoride-free water obtained by using octacalcium phosphate. It can treat water with an initial fluoride concentration of 21 mg/L, reducing contamination to well below the drinkable limit of 1.5 mg/L within 2 h without any negative effects on water quality (Idini et al., 2020).

Thus, we explored the following research questions:

I. Do the latent dimensions of the Extended Parallel Process Model remain stable in the absence and presence of risk communication?
II. Do cognitive-behavioral responses of the Extended Parallel Process Model influence the willingness to pay (WTP) for fluoride-free drinking water produced by the new DT and does this hold for all the behavioral outcomes of the cognitive-behavioral process?

The paper is structured as follows: Section 2 will provide a brief overview of the literature on HRM and the paper's theoretical background. Section 3 will detail the survey and statistical methods used. In Section 4, the results will be presented and discussed. Lastly, Section 5 will conclude.

## 2. Literature review and theoretical background

Four prominent theories are used to make predictions about the effectiveness of fear appeal messages: the Health Belief Model (Becker, 1974; Becker et al., 1978; Rosenstock, 1974), the Parallel Process Model (Leventhal, 1970), the Protection Motivation Theory (Rogers, 1983; Rogers and Deckner, 1975), the Extended Parallel Process Model (Witte, 1992, 1998). All these theories address how people react to fear in different health contexts where the level of susceptibility and/or severity of the threat are triggered by risk messages, while response efficacy statements can be omitted or used to understand how people cope with the problem. According to Witte and Allen (2000, p. 606), efficacy messages are statements that inform recipients that they can perform the fear appeal's recommended actions (self-efficacy) and/or that performing the recommended actions will result in desirable consequences (response-efficacy).

In the Health Belief Model, fear appeals can be conveyed as "cues to action," defined as anything that prompts an individual to consider a health issue. The consideration of a health issue can raise people's perceptions of susceptibility and severity of the disease, thus motivating them to take protective action (Rosenstock, 1974). However, before deciding to act, individuals evaluate the potential benefits of taking the proposed recommended action against the possible psychological, physical, and financial costs, i.e., the perceived barriers. The Health Belief Model has been empirically tested, and results show that perceived barriers and perceived self-efficacy were the main predictors of health-protective behaviors (Carpenter, 2010; Jones et al., 2014).

The Protection Motivation Theory identifies fear appeal components and cognitive mediators for message acceptance. Rogers (1983) proposed a four-way interaction between the two components of perceived threat (severity and susceptibility) and the two components of perceived efficacy (response efficacy and self-efficacy). In Protection Motivation Theory studies, researchers have found that the two threat variables interact with efficacy variables to influence message acceptance (Floyd et al., 2000). However, the Protection Motivation Theory fails to explain when and how fear appeals fail. The Parallel Process Model (Leventhal, 1970) suggests that fear appeals trigger two interconnected processes: danger control (managing the threat) and fear control (regulating fear).

The Extended Parallel Process Model expands the parallel process and protection motivation models, emphasizing factors and mechanisms contributing to danger versus fear control processes and explaining when one process is expected to dominate. According to the Extended Parallel Process Model (see Fig. 1), external stimuli as a health risk message prompts two cognitive mediating processes: assessing the threat and evaluating the efficacy of the recommended response. When people receive a threat message, they first assess their vulnerability (susceptibility and severity). If they feel at risk, they consider the recommended response's effectiveness. If the threat seems low, they ignore the message. In contrast, when people perceive a threat as serious and relevant, fear takes over and motivates them to take action to reduce it. The effectiveness of the action they take (self-efficacy and response efficacy) determines whether they will be encouraged to control the danger posed by the threat or just their fear of it. Suppose people believe they can effectively respond to the threat because of their high self-efficacy and response efficacy. In this case, they will be motivated to focus on controlling the danger by thinking about reducing or eliminating it. When people believe in the recommended response and their ability to act on it, they try to control the danger. If they doubt the effectiveness of the recommended response or their own ability to carry it out, they focus on managing their fear instead, often denying the danger or reacting strongly against it.

In this research, we adopt the approach suggested by Nocella et al. (2023) for the Protection Motivation Theory and modify it within the Extended Parallel Process Model framework. The first objective is to determine whether the items characterizing the latent dimensions of the Extended Parallel Process Model significantly differ in the presence or absence of a fear appeal. The second objective is to assess how elements of the Extended Parallel Process Model affect consumers' WTP for fluoride-free water produced by a new device and to investigate whether this WTP varies under two different risk scenarios.

To analyze how different risk messages affect consumers' WTP for fluoride-free drinking water produced by a new device, two versions of a contingent valuation (CV) survey were created. One version contained no risk information (NRI), while the other included high-risk information (RI).

Nocella et al. (2023) suggest utilizing the scheme developed by Witte and Allen (2000) to analyze the impact of various threat levels and efficacy combinations on people's tendencies to adopt protective behaviors and their WTP for drinking water generated by a new device. According to Witte and Allen (2000), these combinations can create four cognitive different behavioral responses: no response, fear control, low response, and danger control (see Fig. 2).

As shown in Fig. 2, individuals who score low on both the threat and efficacy of the proposed response do not react. They do not perceive any risk and do not think about dealing with the danger. These people seem indifferent to risk messages and do not change their behavior. Their WTP for fluoride-free drinking water should be almost zero, regardless of the presence or absence of risk. Fear control occurs when people have a high perception of threat but a low perception of the efficacy of the proposed response. Even if people are concerned about fluoride in drinking water, they may not believe that the available information or resources, such as a defluoridator, can help them deal with their health concerns. As a result, their WTP may be very low, depending on whether a risk is present or not. This group may engage in maladaptive behavior, which is less effective than taking adaptive action.

People with low response levels score low on feeling threatened and high on believing they can effectively respond to the threat. This group is not particularly afraid of skeletal fluorosis. However, they are likely to adopt adaptive coping behaviors because they trust that the information and resources available can help them deal with fluoride-contaminated water. As a result, they are likely to be willing to pay for adopting protective behaviors, especially when facing a risk. In danger control, people with high threat and perceived efficacy of the response take protective action to reduce the health risks of skeletal fluorosis by drinking fluoride-free water. Consequently, their WTP should be higher than in previous groups.

To address our research questions, we will outline the following research hypotheses:

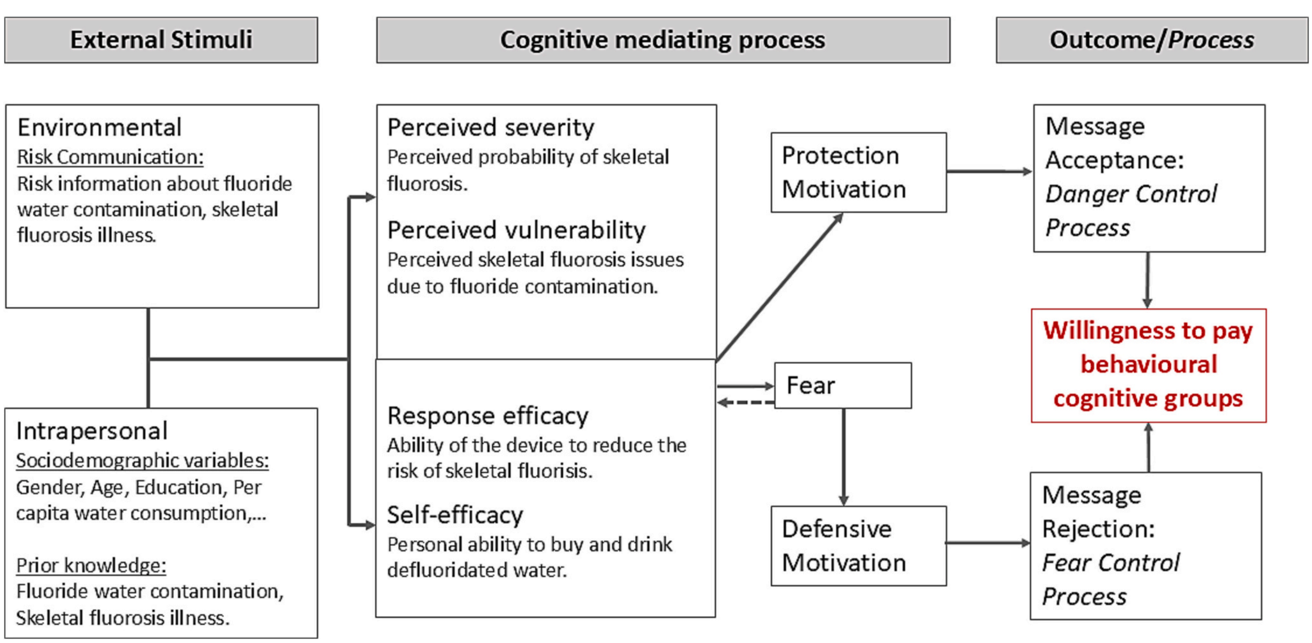


**Fig. 1.** The conceptual framework of the Extended Parallel Process Model (Witte et al., 2001) adapted to our empirical application.

| | | PERCEIVED THREAT | |
|---|---|---|---|
| | | LOW | HIGH |
| PERCEIVED EFFICACY | LOW | *No response*<br>*(No behavioral change)*<br>People do not feel at risk and do not consider coping with the danger anyway.<br><br>*Policy: Enhance education on the risks of drinking water containing high fluoride concentrations and propose solutions.* | *Fear control*<br>*(Maladaptive coping behavior)*<br>People are scared but do not believe they will cope with the danger.<br><br>*Policy: Enhance education about proposed solutions* |
| | HIGH | *Low response*<br>*(Adaptive coping behavior)*<br>People are not scared but believe they will cope with the danger.<br><br>*Policy: Enhance education on the risks associated with drinking water containing high concentrations of fluoride* | *Danger Control*<br>*(Protective behavior)*<br>People are determined to take protective action to avoid or reduce the threat.<br><br>*Policy: Provide calls to action* |

**Fig. 2.** Behavioral outcomes of the Extended Parallel Process Model cognitive process.

**Hypothesis A. (HA):** In the absence of risk, the importance of the items characterizing the latent dimensions of the Extended Parallel Process Model significantly differs from the Extended Parallel Process Model's constructs in the presence of risk.

**Hypothesis B. (HB):** Consumers are more willing to pay for fluoride-free water produced by a new DT when they receive risk communication than when they don't. This holds for all the behavioral outcomes in the Extended Parallel Process Model cognitive process, as shown in Fig. 2.

## 3. Methods

We analyzed the impact of a low and high-risk message concerning fluoride water contamination through a quasi-experimental contingent valuation (CV) survey to motivate people to protect themselves from the risk of skeletal fluorosis. We follow the methodology proposed by Nocella et al. (2023) to link behavioral responses to the WTP for fluoride-free water produced by a new DT system (Idini et al., 2020).

The study aimed to collect data on the three elements of the Extended Parallel Process Model framework: sources of information, cognitive mediating processes, and purchasing behavior (as depicted in Fig. 1).

### *3.1. Sources of information*

To study the impact of various risk messages on people's WTP for water free of fluoride supplied through a new device, we administered a questionnaire to a sample of rural populations living in Arusha areas (Tanzania) affected by natural fluoride contamination of groundwater. The first section of the survey provided all participants with information about skeletal fluorosis and its impact on personal discomfort and reduced quality of life. Then, participants were randomly split into two groups (refer to Section 3.3 for sampling and data collection). The NRI group did not receive any news about fluoride contamination in groundwater. The RI group was informed that there was a severe risk to their health of contracting skeletal fluorosis due to groundwater fluoride contamination. In this group, the fear appeal was triggered by administering the following information:

> '*According to the World Health Organization (WHO) and many medical studies, drinking water with high fluoride concentrations can increase the risk of getting skeletal fluorosis disease. This disease can severely and permanently affect your bones and those of your family. The concentration of fluoride in groundwater in your area is likely to exceed the 1.5 mg/L guideline limit recommended by the Tanzanian Government and WHO. In the Arusha and Manyara regions, over 50% of groundwater sources exceed the fluoride 1.5mg/L limit. This means that fetching and drinking water without removing fluoride greatly increases the probability of you and your family developing skeletal fluorosis disease (*here, participants were shown pictures of individuals affected by skeletal fluorosis).
>
> To effectively address the issue of fluoride in drinking water, you must drink water free of fluoride. We are proud to announce the launch of a revolutionary and simple device that provides such fluoride-free water. Kiosks in your area will be equipped with this new device, where you can collect free fluoride water for you and your loved ones.'

Both groups of individuals were asked to identify their primary drinking water sources, express concerns about drinking safe water, and detail their methods of consuming safe water. A specific section of the questionnaire, directed at both groups of participants, was aimed at introducing participants to the new device (Idini et al., 2020) engineered under the 'FLOWERED' H2020 project (https://cordis.europa.eu/project/id/690378). It was stressed that the new DT can provide fluoride-free water through a simple process that requires minimal energy. It operates on a rechargeable battery, which can be powered by solar panels or generators. Additional accessories for other water treatment methods can be added to the device, making it an ideal solution for rural areas.

Several studies, as predicted by the Extended Parallel Process Model, suggest that messages containing fear appeals along with recommendations can be more effective than messages with recommendations alone (Harris and Jellison, 1971). Thus, combining high-threat and high-efficacy messages could generate strong and stable attitudes, intentions, and behavior change.

### 3.2. Operationalizing the cognitive mediating process

The different components of the Extended Parallel Process Model were developed using examples of wording from review papers and studies exploring the health aspects of contaminated drinking water (Witte et al., 1996). These examples were then adapted to suit the context of this investigation. In the survey, all elements of the Extended Parallel Process Model cognitive mediating process (as shown in Fig. 1) were measured using a five-point Likert scale ranging from "completely disagree" (−2) to "completely agree" (+2).

Perceived severity, the individual's beliefs about the seriousness of the threat, was measured using three questions regarding respondent's beliefs that skeletal fluorosis: (i) affects the quality of life badly, (ii) decreases mobility seriously, (iii) is extremely harmful. The level of perceived vulnerability was assessed based on the following set of statements: (i) I am at risk of getting skeletal fluorosis, (ii) it is very likely that I will contract skeletal fluorosis, and (iii) it is possible that I will contract skeletal fluorosis.

Statements linked to response efficacy were assessed by three items: (i) I am sure that this new device can work to prevent skeletal fluorosis, (ii) drinking free fluoride water from this new device will effectively prevent skeletal fluorosis, (iii) if I drink free fluoride water produced by this device, I will be less likely to get skeletal fluorosis. Perceived self-efficacy was extracted by asking respondents' beliefs about their ability to perform the recommended response. Three statements were also used in this case: (i) I would like to collect and buy free-fluoride water, (ii) it will be easy to drink free-fluoride water produced by the new device, (iii) collecting fluoride-free water produced from the new device to prevent skeletal fluorosis will be convenient.

The adaptive response cost was measured by developing a contingent valuation (CV) scenario, a widely used method in non-market valuation research. This technique required the development of a hypothetical market scenario where respondents had to express their maximum WTP for 20 l of free-fluoride water produced by the new device. WTP was elicited into two steps. During the first step, respondents had to express their intention to buy 20 l of fluoride-free water produced by the device. In the second step, participants who did not intend to buy the water had to indicate why they were unwilling to buy it. The inclusion of this question was important for discriminating protest responses. Instead, participants interested in purchasing the free-fluoride water were asked to state their maximum WTP using a double bound contingent valuation method (DB-CVM) (Hanemann et al., 1991). With DB-CVM, respondents are first asked if they are willing to pay a specific amount (bid) for a particular good, in our case 20 l of fluoride-free water produced by the new device. If respondents answer no to the first bid, they are offered a lower price; otherwise, if they respond yes, they receive a higher price. This method is easier to administer than other willingness CV techniques that may require lengthier adjustment processes, such as the bidding game. The DB-CVM is also simpler than the open-ended elicitation technique, which requires an individual to evaluate their reserve price through self-analysis. The data collected with the DB-CVM provides an interval of values containing the person's true WTP.

### 3.3. Modelling the extended parallel process model latent dimension and Wtp for fluoride-free water

Although the Extended Parallel Process Model is a well-established conceptual framework, we had to conduct a factor analysis to validate its latent dimensions in each treatment group, NRI and RI, which were investigated in this study. This was necessary to test our hypothesis and determine the latent scores used in the econometric analysis. The outcomes we were interested in contained the eight previously described as preventive measures. To reduce the dimensionality of the Extended Parallel Process Model, we performed a factor analysis using polychoric correlations to identify the latent scores using the set of items presented in Section 3.2. Some studies have shown that the latent scores obtained using polychoric correlations provide a more accurate reproduction of the measurement model used to generate the data (Holgado-Tello et al., 2008).

Hypothesis A was assessed, determining whether the *i*-th Extended Parallel Process Model latent scores (Ls) were similar or different in the absence or presence of risk:

$$HA_0 : Ls_{i,NRI} \geq Ls_{i,RI};$$

$$HA_1 : Ls_{i,NRI} < Ls_{i,RI}.$$

The latent scores (Ls) were also used in the econometric analysis of consumers' WTP, which is the price for fluoride-free water produced by the new device using a new, more effective process. Given the double-bound contingent valuation methodology used to define the dependent variable ($y^* = WTP$), interval regression models were estimated for our different treatment groups, NRI and RI. The model specification was similar to that proposed by Nocella et al. (2023). The independent variables included were four Extended Parallel Process Model latent scores, specifically perceived efficacy (*PE*) identified from the six items connected to perceived response-efficacy and perceived self-efficacy, fear (*Fear*), perceived severity (*PS*), and perceived vulnerability (*PV*). In addition, we checked the importance of the following socio-demographic variables: (i) *Gender,* indicating whether respondents are male or not; (ii) *Education,* indicating the level of education of respondents, i.e., no education, primary education, secondary education, or higher education; (iii) *Age* indicating the age of respondent; (iv) *Per-capita water consumption* indicating the weekly average water consumption of respondent's household; (v) *Maasai* if the respondent was of ethnicity Maasai; (vi) *Water Fluoride Contamination* indicating whether respondents have previous knowledge of fluoride contamination of groundwater in her/his area; (vii) *Skeletal Fluorosis Illness* that check if respondent has ever heard about skeletal fluorosis illness before the study.

Finally, the distributions of estimated participants' WTP were compared across four possible behavioral responses: 'no response,' 'low response,' 'fear control,' and 'danger control,' as presented in Fig. 2.

To complete this task, we focus on the latent *Perceived Efficacy* and *Threat* scores. The *Threat* variable was identified as the *sum of the Perceived Severity and Perceived Vulnerability* latent scores. We first standardize both variables, *Perceived Efficacy and Threat*, by subtracting their respective means and dividing them by their standard deviations. Negative standardized scores indicate low perceived efficacy and threat levels, while non-negative scores indicate high levels. Respondent segmentation across the four cognitive-behavioral responses was achieved through combinations of low and high scores, as illustrated in Fig. 2.

Expected WTP values were predicted using an interval regression model and compared across respondents with the four *k* different cognitive-behavioral responses ($k = 1, \ldots, 4$), i.e. no response, fear control, low response and danger control, and across the two treatment groups, NRI and RI, using independent sample *t*-tests. Thus, hypothesis B was tested in the following way:

$$HB_0 : WTP_{k,NRI} \geq WTP_{k,RI};$$

$HB_1: WTP_{k,NRI} < WTP_{k,RI}$.

### 3.4. Sampling and data collection

The study targeted mainly the two main ethnic groups that embody the culture, lifestyle, and farming practices of rural communities in the region, namely the Meru and Maasai. The Meru are the dominant group, and their main source of income is small-scale farming. The Maasai are semi-nomadic pastoral farmers who inhabit the dry lands. Participants in this study were randomly recruited from five rural villages: Engutukoit, Lemanda, Losinoni Kati, Losinoni Juu, and Lemongo, located in the Arusha region of Tanzania, by a non-governmental organization (NGO) operating in the area. The survey was conducted using a face-to-face format by a team of native speakers employed by the local NGO. The interviewers received four days of training on the questionnaire content, survey techniques, and ethical considerations provided by the researchers involved in the study. The electronic questionnaire, created using the Qualtrics platform, was originally written in English and then translated into Swahili and Nilotic languages by researchers and native-speaking NGO personnel. The Qualtrics platform allowed the collection of online or offline data. The interviewer primarily met with the participants at their homes, where they read out information, messages, and questions and recorded the respondents' answers using a mobile device. The survey was piloted at the beginning of September 2023 with 50 respondents and ended in November 2023. Formal consent was required from each participant before starting the investigation. The questionnaire took approximately 15 min, and no personal information was needed to ensure anonymity. The final survey's sample included 726 participants randomly assigned to either the NRI or RI group using the Qualtrics platform. The study received ethical approval from the University of Sassari Ethics Committee.

## 4. Results

The following section presents the results of the effect of Witte (1992) four types of behavioral responses (no response, fear control, low response, and danger control) on the amount of money participants were willing to pay for fluoride-free water. In this section, we also examined how these responses were influenced by the presence or absence of information about health risks associated with fluoride-contaminated groundwater.

### 4.1. Socio-economic characteristics

The socio-economic characteristics of the sample are very similar across the NRI and RI treatment groups. For both groups, 64 % of the participants were Meru, 35 % were Maasai, and the remaining respondents identified with other ethnic groups; 45 % were female, with an average age of 39 and an average family size of 5 members. Regarding education, 53 % of respondents had a primary school diploma, 19 % held a secondary school diploma or higher, and 28 % were unsure of their level of education or had no education at all. Regarding their primary sources of income, 66 % of respondents reported that it came from farming, while 30 % derived income from selling animals such as goats, sheep, and poultry, as well as livestock products like milk, eggs, and meat.

Regarding water habits, most participants (80 %) obtained their drinking water from boreholes. The rest had access to piped water within their dwellings or compounds, making up 19 % of the total. On average, each person consumes a little <12 l of water daily for drinking and cooking purposes. This amount is slightly more than the 7.5 l of minimum water necessary for hydration and incorporation into food for most people and conditions, as per the World Health Organization's standards (WHO, 2011). Most respondents reported spending less than a half hour going to the water source, fetching water, and returning home. This task is predominantly carried out by women, including adult and child females, six days a week. They store water for up to a few days, primarily using plastic drums. Finally, less than one-third of respondents (26.8 %) pay for the water they fetch and drink.

Concerning water safety beliefs, over half of the respondents (53.7 %) believe that the water they drink is unsafe and take measures, such as boiling it (a practice that does not affect the fluoride content in water), to increase its safety. Only 6.3 % of respondents declared filtering drinking water. What worried most respondents (31.6 %) about drinking unsafe water was the brown discoloration of teeth, one of the first signs of fluorosis illnesses. However, according to the survey's results, fewer than 20 % of respondents recognized water as a potential source of disease for both adults and children.

### 4.2. Latent dimensions of the Nri and Ri cognitive mediating process

Table 1 reports the descriptive statistics of 15 variables used to identify Extended Parallel Process Model latent dimensions by treatment group, including fear, perceived severity, perceived vulnerability, perceived self-efficacy, and perceived response efficacy.

Table 2 presents the main statistics that allow a comparison of the latent scores between the two NRI and RI treatment groups.

All the latent scores, except for the Fear latent score, showed higher values for the group of RI respondents, but the differences were not statistically significant to the independent sample *t*-tests. Thus, we reject HA as the differences in Ls are not statistically significant.

### 4.3. Wtp for defluoridated water and relative differences in behavioral responses

Table 3 reports the estimated parameters of the interval regression specifications for the two treatment groups. All the independent variables have been previously standardized to compare their impacts on the WTP in buying fluoride-free water produced by a new device and a new process.

The estimated coefficients for the cognitive process show different impacts on WTP with (RI) and without (NRI) risk information. The coefficients for the *FA* variable were positive and significant in both regressions. Thus, for both groups of individuals, the study found that those with higher levels of fear were willing to pay more for fluoride-free water. More specifically, participants in the NRI group were willing to pay TZS 49 (US$ 0.02) more for a one-point increase in the *FA* score, while for the RI group this amount the WTP was only TZS 27 (US$ 0.01). Conversely, perceived efficacy does not seem to influence WTP. The estimates were not significant in both regressions.

These results indicate that perceived efficacy is not a significant cognitive factor, regardless of whether risk information is provided or not. It is interesting to note that the measure of the impact of perceived severity on WTP is not significant for both groups of individuals. Conversely, for the perception vulnerability variable *PV,* the coefficient is positive and significant in both regressions. The estimation results suggest that when the PV score increases by one, the WTP for fluoride-free water increases by TZS 47 (US$ 0.02) in the no-risk information scenario. This amount is higher in the risk information scenario. The WTP increases by TZS 65 (US$ 0.03) in this case. As mentioned earlier, the results may be influenced by the fact that the respondents experiencing high levels of risk feel more vulnerable due to the information they have received. They are willing to pay more for fluoride-free water, even if they are not confident that the water purifying device will effectively reduce the chances of experiencing negative health outcomes due to fluoride contamination.

The estimation results of the socio-demographic factors and individuals' previous knowledge of fluoride contamination and skeletal fluorosis illness are now briefly discussed. These factors help in estimating the WTP, which will be used to compare fluoride-free water prices across the four possible behavioral responses of threat and

**Table 1**
Descriptive statistics of Extended Parallel Process Model variables across treatment groups.

| Extended Parallel Process Model Latent scores | Variables | Items[b] | NRI mean[a] | RI mean[a] |
|---|---|---|---|---|
| Fear | Fear1 | I am concerned about the information regarding skeletal fluorosis. | 0.68 (1.67) | 0.62 (1.72) |
| | Fear2 | The skeletal fluorosis disease causes me anxiety. | 1.24 (1.32) | 1.25 (1.36) |
| | Fear3 | Skeletal fluorosis disease frightens me. | 1.56 (1.04) | 1.53 (1.09) |
| Perceived Severity | PS1 | I believe that skeletal fluorosis badly affects the quality of life. | 1.72 (0.79) | 1.77 (0.65) |
| | PS2 | I believe that skeletal fluorosis decreases mobility seriously. | 1.87 (0.56) | 1.86 (0.57) |
| | PS3 | I believe that skeletal fluorosis is extremely harmful. | 1.80 (0.76) | 1.85 (0.61) |
| Perceived Vulnerability | PV1 | I am at risk of getting skeletal fluorosis. | 0.23 (1.67) | 0.22 (1.66) |
| | PV2 | It is very likely that I will contract skeletal fluorosis. | −0.15 (1.62) | −0.01 (1.65) |
| | PV3 | It is possible that I will contract skeletal fluorosis. | −0.22 (1.67) | −0.15 (1.66) |
| Perceived Response Efficacy | RE1 | I am sure that this new device can work to prevent skeletal fluorosis. | 1.54 (0.67) | 1.47 (0.79) |
| | RE2 | Drinking free fluoride water from this new device will effectively prevent skeletal fluorosis. | 1.51 (0.78) | 1.63 (0.64) |
| | RE3 | If I drink free fluoride water produced by this device, I will be less likely to get skeletal fluorosis. | 1.60 (0.73) | 1.60 (0.66) |
| Perceived Self-Efficacy | SE1 | I will go to a kiosk to collect free fluoride water produced by the new device to prevent skeletal fluorosis. | 0.89 (1.66) | 1.05 (1.59) |
| | SE2 | It will be easy to drink free fluoride produced by the new device to prevent skeletal fluorosis. | 1.59 (0.71) | 1.67 (0.60) |
| | SE3 | Collecting free fluoride water produced from the new device to prevent skeletal fluorosis will be convenient. | 1.55 (0.78) | 1.60 (0.71) |

[a] In brackets standard deviations.
[b] Items measured on a five-point Likert scale ranging from 'completely disagree' to 'completely agree.'

efficacy cognitive strategies (Nocella et al., 2023; Witte, 1992; Witte and Allen, 2000). As discussed in Section 4.1, both treatment groups' socio-demographic characteristics and previous knowledge are quite similar. However, their impact on WTP differs significantly. The WTP of the NRI group was significantly sensitive to per-capita household water consumption and a dummy variable linked to respondents' prior knowledge of fluoride contamination in their area. Respondents aware of water fluoride contamination were willing to pay TZS 46 (US$ 0.02) more than those unaware of the issue. Being female, belonging to the Maasai ethnicity, having a higher level of education, and being of a higher age all lead to a greater and significant WTP for water free of fluoride among the RI group. Respondents who were already aware of fluoride contamination in the area were also found to have a higher WTP, similar to the NRI group. However, unlike the NRI group, the level of per capita water consumption did not significantly impact WTP.

Since all covariate variables were standardized in the regressions, the constant represents the average WTP for 20 L of fluoride-free water. The expected value of purchasing fluoride-free water has been estimated to be TZS 347 (US$ 0.14) for the group of RI respondents and TZS 315 (US$ 0.13) for the NRI treatment group. This shows that informing people of the risks associated with consuming fluoride-contaminated water increases their WTP by >10 %. Moreover, because the median was higher than the average, the WTP distributions for the NRI and RI groups were skewed to the left.

In Table 4, we report the WTP estimates to test hypothesis B, which is relevant for analyzing whether the differences in WTP estimates between the two groups of respondents, NRI and RI, are statistically

**Table 3**
Determinants of WTP for fluoride-free water

| Variables | NRI GROUP[b] $\beta_i$ | RI GROUP[b] $\beta_i$ |
|---|---|---|
| Cognitive constructs | | |
| Fear (FA) | 48.76 (3.42)** | 27.19 (1.98)* |
| Perceived Efficacy (PE) | −8.08 (−0.69) | 1.14 (0.08) |
| Perception Severity (PS) | −21.89 (−1.68) | 6.21 (0.39) |
| Perception Vulnerability (PV) | 47.36 (3.00)* | 64.84 (4.08)*** |
| Socio-demographics | | |
| Female (Fe) | 6.76 (0.53) | 30.49 (2.10)* |
| Age | −0.42 (−0.03) | 33.89 (2.08)* |
| Education (Edu) | −2.51 (−0.18) | 38.59 (2.39)* |
| Per-capita water consumption (PCW) | 51.30 (3.41)** | 20.87 (1.30) |
| Maasai | 6.70 (0.46) | 63.93 (4.11)*** |
| Previous knowledge | | |
| Water Fluoride contamination (WFC) | 46.29 (3.32)** | 78.51 (5.80)*** |
| Skeletal Fluorosis Illness (SFI) | 2.42 (0.21) | −10.57 (−0.65) |
| Intercept | 314.72 (24.62)*** | 347.20 (24.18)*** |
| N | 363 | 363 |
| Loglikelihood | −482.17 | −494.38 |
| Sigma | 197.17 | 219.04 |
| Mean WTP (TZS) | 314.72 | 347.20 |
| Median WTP (TZS) | 316.43 | 359.35 |

[b] In brackets t-statistics, *, ** and ***indicate significance at $p < 0.05$, $p < 0.001$ and $p < 0.0001$, respectively.

**Table 2**
Comparison between NRI and RI descriptive statistics of Extended Parallel Process Model latent scores.

| Extended Parallel Process Model latent dimensions | NRI[a] | | | RI[a] | | | Mean comparison *t*-test[b] |
|---|---|---|---|---|---|---|---|
| | Mean | Min | Max | Mean | Min | Max | |
| Fear | 1.23 (1.14) | −2.00 | 2.00 | 1.22 (1.18) | −2.00 | 2.00 | 0.08 (0.53) |
| Perceived efficacy | 2.95 (0.96) | −2.60 | 3.79 | 3.05 (0.89) | −0.52 | 3.79 | −1.35 (0.08) |
| Perception severity | 1.79 (0.47) | −2.00 | 2.00 | 1.82 (0.42) | −0.79 | 1.99 | −0.73 (0.23) |
| Perception vulnerability | −0.04 (1.43) | −2.00 | 2.00 | 0.02 (1.47) | −2.00 | 2.00 | −0.62 (0.27) |

[a] In bracket standard deviation.
[b] In brackets pvalues, *, ** and *** indicate significance at $p < 0.05$, $p < 0.001$ and $p < 0.0001$, respectively.

**Table 4**
Comparison of WTP estimates by cognitive-behavioral groups.

| No Response | | | Fear Control | | |
|---|---|---|---|---|---|
| Model | WTP[b] | WTP t-statistics | Model | WTP[b] | WTP t-statistics[a] |
| NRI (118)[c] | 259 | −1.83 | NRI (36)[c] | 345 | −1.49 |
| RI (106)[c] | 283 | | RI (36)[c] | 374 | |
| **Low Response** | | | **Danger Control** | | |
| Model | WTP[b] | WTP t-statistics[a] | Model | WTP[b] | WTP t-statistics[a] |
| NRI (93)[c] | 259 | 0.18 | NRI (116)[c] | 407 | −3.11** |
| RI (84)[c] | 256 | | RI (137)[c] | 447 | |

[a] *, ** and ***indicate significance at $p < 0.05$, $p < 0.001$ and $p < 0.0001$, respectively.
[b] TZS for 20 l of fluoride-free drinking water.
[c] In parentheses, the number of individuals.

significant using independent sample *t*-tests.

Four independent sample t-tests were conducted to compare the expected value of the distributions. The results are presented in Table 4. The average WTP for fluoride-free water in NRI was generally lower than in RI, except for the 'low response' scenario. However, a significant difference was found only for the 'danger control scenario,' where the WTP in NRI was significantly lower than in RI. Thus, the null hypothesis B (HB) of a WTP was more for the RI group than the NRI group, and it was not rejected only in the case of danger control. According to the results, when individuals have access to information, they tend to adopt protective behavior even if it comes at a higher cost. This suggests that, differently from RI individuals, the NRI respondents did not find the device effective in mitigating the risk of fluoride contamination in water (low levels of perceived efficacy) and, hence, were not motivated to pay more to protect themselves.

Looking at Table 4, we observe that 35 % of the participants belong to the danger response cognitive segment, while 31 % are in the no response segment, regardless of whether they are associated with the NRI or RI groups. Finally, 24 % of individuals are associated with the low response segment, while the remaining 10 % are linked to the fear control segment. These results may indicate the need for specific policy actions, which will be discussed in Section 5.2.

The estimated WTP distributions of four different cognitive segments were also compared using kernel density estimation, as presented in Fig. 3. All distributions indicate a unique peak in WTP values, with the highest peak observed in the case of 'danger control' (TZS 504, US$ 0.20). Fig. 3 also shows interesting differences between the estimated WTP values for the non-risk-informed (NRI) and risk-informed (RI) scenarios, with the highest differences observed for the 'fear control' and 'danger control' behavioral responses.

## 5. Discussion

### 5.1. Theoretical contributions and implications

This study examines the responses of individuals living in rural areas of Tanzania, not served by water purification services, to the risk of fluoride-contaminated water in three ways. First, it compares how the elements of the Extended Parallel Process Model impact the adoption of preventive behavior in the absence and presence of risk. Second, it incorporates elements of the Extended Parallel Process Model into a contingent valuation survey designed to elicit WTP for purchasing fluoride-free drinking water produced by a new device. Following the approach suggested by Nocella et al. (2023) and the hypotheses developed by Witte's extended parallel processing model (Witte, 1992; Witte and Allen, 2000), we tested how different combinations of threat levels and response efficacy predict people's WTP for fluoride-free water to threaten messages.

According to the results, participants' cognitive process and perceived risk were not significantly affected by messages conveying different levels of risk. Individuals who received a threatening message about the high likelihood of fluoride water contamination, along with information on how to prevent it by using a new water filtering device, showed higher scores of perceived threat and response efficacy compared to those who did not receive this message. This finding seems to confirm the Extended Parallel Process Model's expected results of the relevance of fear appeal. However, we noted no statistically significant differences in scores. Various factors may explain this behavior. First, previous familiarity with the threat and/or responses, as in our study, where 32 % of participants showed prior knowledge of the relationship between fluoride water contamination and fluorosis, could affect message processing in important ways. For example, Muthuswamy et al. (2009) found that when the audience is already scared, the threat level

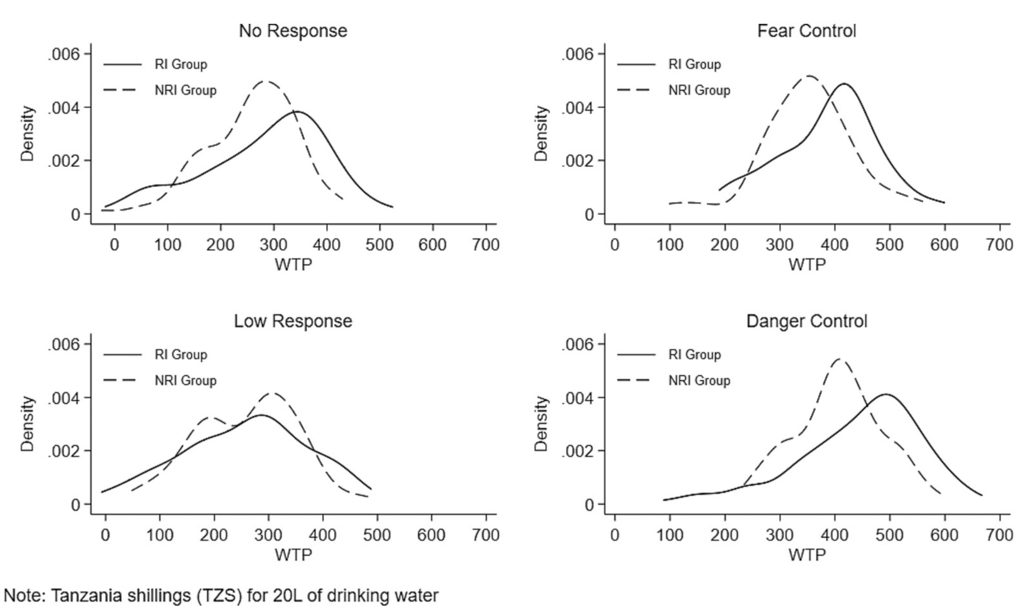


**Fig. 3.** Comparison of fluoride-free water's WTP estimates by cognitive-behavioral groups.

in the message makes little difference to the subsequent level of fear and does not influence attitudes, intentions, and behavior. Similar findings were reported by McKay et al. (2004) and Popova (2012). Secondly, individuals may often underestimate their actual risk of acquiring infections compared to the severity of the diseases, Abdelmagid et al. (2022). Further, they may tend to view the risk of infection as being higher than the risk to themselves, a phenomenon known as 'unrealistic optimism' (Abdelmagid et al., 2022; Weinstein, 1982). This may suggest that there may not be statistically significant differences in the perceived risk of contracting skeletal fluorosis between the non-risk-informed (NRI) and the risk-informed (RI) groups.

Although we did not find significant score differences in the components of the Extended Parallel Process Model between the RI and NRI groups, the fear of developing skeletal fluorosis and the perceived vulnerability from drinking water with high fluoride content positively influenced the WTP for fluoride-free water in both groups of individuals. The influence of fear on WTP was greater among individuals who were not exposed to the risk message, while the opposite held true for the perceived vulnerability variable, where the influence was greater among participants who received the risk message. The perceived efficacy of the response was not significant in either group of individuals.

Therefore, policymakers involved in risk communication should pay particular attention to perceived vulnerability as the primary motivating factor for precautionary behavior. The relative importance of perceived vulnerability with respect to other cognitive constructs was also documented in Nocella et al. (2023) and Jansen et al. (2021).

In our study, we found that the individuals who were exposed to the risk message showed a 10 % higher WTP compared to those who were not exposed to the risk. This indicates that informing people about the risks of consuming fluoride-contaminated water increases their WTP. In addition, women, individuals with higher education, and older people are more willing to pay for fluoride-free water within the informed group. Respondents already aware of fluoride contamination in the area indicated a higher WTP, regardless of their risk group.

Finally, the average WTP for fluoride-free water in a no-risk situation was generally lower than for people exposed to risk, except for the 'low response' scenario. Therefore, based on the results, when individuals have access to information, they exhibit protective behavior even if it comes at a higher cost.

### 5.2. Implications for policies

To the best of our knowledge, this is the first study to explore how elements of the Extended Parallel Process Model can affect WTP for water obtained from de-fluoridation technologies. This technology can assist individuals living in fluoride-contaminated areas in adopting protective behavior by providing them with access to safe drinking water.

The study revealed that although de-fluoridation technologies can be considered one of the best methods for treating fluoride-contaminated water in rural areas, individuals are unaware of the importance of using these technologies to protect themselves from the risk of skeletal fluorosis illness. In this respect, our results confirm findings from other studies (Burt et al., 2017; Lilje and Mosler, 2017). Further, in a risk communication scenario, participants in the 'danger control' category were willing to pay 10 % more for water obtained from de-fluoridation technologies than in a situation with no risk. Furthermore, according to the results in Table 4, 35 % of the participants know the risk of developing skeletal fluorosis disease and how to protect themselves by drinking water purified using de-fluoridation technologies. Otherwise, 65 % of participants lack the necessary knowledge regarding the risks and/or the appropriate responses they can take. Thus, the rural population affected by fluoride-contaminated water requires better collaboration between governmental and non-governmental institutions to enhance education through effective communication strategies. This strategy can be important to raise awareness about the benefits of de-fluoridation technology, develop effective information campaigns, and advertise the technology appropriately. Furthermore, communication campaigns using the Extended Parallel Process Model framework should help audiences develop a realistic perception of the risks associated with skeletal fluorosis when consuming water with high fluoride levels.

## 6. Conclusions

We explore how fear messages about the risk of getting skeletal fluorosis from drinking water with high fluoride concentrations and the perceived effectiveness of a de-fluoridation technology can influence behavioral decisions. The study uses the Extended Parallel Process Model that predicts four types of actions. If people do not perceive a risk and do not believe they can handle the danger, they will not take any action. If they feel scared but do not believe they can handle the danger, they will adopt self-defeating or maladaptive actions (fear control). Instead, people will take self-protective measures if they believe in the solution's effectiveness and are confident to implement it (danger control). However, they may adopt less danger control if they know how but are not motivated to act (low response).

This study found that the Extended Parallel Process Model latent constructs' scores revealed higher values for those who received the fear message, but the differences were not statistically significant. However, when we examined how different threat levels and the effectiveness of protective measures influence people's inclination to adopt safety measures and their WTP for drinking water from a new defluoridator, we found that individuals in the danger control group are more inclined to engage in protective behavior. As a result, they are more willing to pay a higher price for fluoride-free water than those in other groups. Thus, individuals in other groups may need targeted risk communication campaigns to encourage similar precautionary behavior. To facilitate this shift, policymakers might consider creating educational campaigns to raise awareness about risks and solutions for individuals with a low response to the risks.

## CRediT authorship contribution statement

**Luciano Gutierrez:** Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Carlo Sanna:** Conceptualization. **Maria Sabbagh:** Formal analysis, Data curation. **Giuseppe Nocella:** Methodology. **Alfredo Idini:** Investigation, Data curation, Conceptualization. **Alberto Carletti:** Data curation. **Franco Frau:** Investigation.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: LUCIANO GUTIERREZ reports financial support was provided by Autonomous Region of Sardinia. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

The data that has been used is confidential.

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