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REVISED Using evidence-based models of human behaviour to reduce endocrine-disrupting chemicals exposure: recommendations for strengthening interventions

[version 2; peer review: 4 approved, 1 approved with reservations]

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Abstract

Endocrine-disrupting chemicals (EDCs) represent a threat for the ecosystem and human health. Exposure routes include modifiable exposures, such as choice of food or cosmetics but also daily habits such as airing the room. However, current attempts to reduce modifiable exposure often rely on knowledge provision and awareness-raising campaigns. This is the case even though human behaviour, decision making and habits change have been studied for a long time, and numerous psychological theories demonstrate that the transition from awareness of a health threat to actually change daily behaviour is not straightforward. This paper calls for

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interventions on EDCs exposure reduction to build on solid understanding of human behaviour and use of behaviour change techniques to achieve significant impact. We illustrate how this can be done by presenting the HYPIEND project, a multicomponent behavioural intervention designed to help pregnant women and prepubertal children (and their parents) to reduce their modifiable exposure to EDCs in these sensitive periods. HYPIEND relies on theoretical models such as the Health Action Process Approach (HAPA) model, motivational interviewing techniques, and broader support through partners (for pregnant women) and the school environment (for children) through a school-wide project built on the School Wide Positive Behavioural Interventions Supports.

Keywords
Endocrine disruptors; Awareness raising; information deficit model; Health Action Process Approach (HAPA); School Wide Positive Behavioural Interventions and Supports (SWPBIS); Behaviour change techniques (BCTs); Lifestyle interventions

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REVISED **Amendments from Version 1**

The new version of the paper contains the following changes:

- clarification of the manuscript main contribution by presenting more explicitly its aim (conceptual) and revision of the wording that wrongly implied demonstrated effectiveness of the project while it is a trial in progress.
- addition of theory of changes tables for each study (in appendix).
- justification of the use of the HAPA framework and the BCT taxonomy.
- more explicit discussion of other types of actions (regulatory, industrial, policy level) and how behavioural approach are related.
- equity considerations are now mentioned (in terms of inequity in exposition to EDCs and socio-economic constraints to access alternatives).
- mention of the list of EDCs that are included in the HYPIEND project.
- more precise description of the cited studies (sample size, characteristics of the participants, effect sizes).
- geographical scope for the mention of EDCs in the environment extended beyond Europe.
- mention of the impossibility to test individual elements of the intervention as a limit, and reference to multiphase optimization strategy (MOST) as a possible solution for future studies.
- inclusion of breast milk and placenta as routes of exposure to EDCs.
- addition of two studies that were not cited in the earlier version of the paper.
- mention of the timeframe to develop habits.
- mention of the group size for the workshops in HYPIEND.
- more detailed explanation of the process of behaviour change in the school intervention.
- brief mention of EDC-related biological outcomes measures.

Any further responses from the reviewers can be found at the end of the article

Abbreviations list

BCTs: Behaviour change techniques
EDCs: Endocrine-disrupting chemicals
HAPA: Health Action Process Approach
PFAS: Per- and polyfuoroalkyl substances
RCT: Randomized Controlled Trial
SWPBIS: School Wide Positive Behavioural Interventions and Supports

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Context

The Endocrine Society defines an endocrine disrupting chemical (EDC) as: "an exogenous chemical, or mixture of chemicals, that can interfere with any aspect of hormone action".[1,2] Among EDCs, some naturally occurring compounds can be found[3]; however, most of them are synthetic, human-made chemicals. According to estimates of the European Environment Agency, approximately 70% of around 100,000 chemicals on the EU market have been poorly assessed for their safe use.[4] A significant number of them have been found to disrupt the endocrine system. As of June 2025, 227 substances were identified as EDCs at the EU level (List I), and additional 104 substances are currently under evaluation (List II). Importantly, the Global Chemical Outlook II states that global trends, such as population dynamics, urbanisation, and economic growth, are rapidly increasing chemical use, particularly in emerging economies.[5] Recent studies all around the globe have demonstrated the presence of EDCs in the environment.[6–8]

EDCs can have substantial impact on ecosystem and human health.[1] For instance, they can induce a wide array of reproductive and developmental disturbances in aquatic species,[9,10] as well as in birds and mammals.[9] Studies conducted in grassland and freshwater ecosystems have demonstrated that EDCs-induced disturbances can lead to reductions in both biomass and the capacity for ecosystem recovery.[10] Regarding human health, EDCs can interfere with endogenous hormone biosynthesis, metabolism, or action, disrupting homeostatic and developmental processes.[11] Epidemiological and experimental studies have linked EDCs exposure to impaired reproductive function, immune impairment, neuro-developmental deficits, metabolic disorders, and hormone-dependent cancers.[12]

Interventions and communication campaigns are developed to reduce EDCs exposure. However, many of them rely on knowledge provision, with the idea that awareness raising is sufficient to induce behaviour change. For example, in their chapter *Policy implication and community interventions to reduce EDCs exposure*, Montano and Guglielmino propose that "information campaigns could be organized for the general population or population particularly exposed to EDCs. An action of this dimension could change exposure levels by informing and raising awareness of how to avoid the possible and different contact with individual EDCs and defend health from the sneaky snare of EDCs".[13 p.221] Decades of work in behavioural sciences have demonstrated how the process is complex[14]; and provide insights on how people change their habits. This paper is a call to use this scientific knowledge to build interventions that maximise their chances to ultimately have substantial impact on ecosystem and human health. We begin by discussing routes of exposure to EDCs, especially behavioural ones, before reviewing models of behaviour change. We then present examples of successful and less successful studies and campaigns, analysed through the prism of psychological determinants and behaviour change techniques. The HYPIEND project is then presented for illustrative purpose as an example of an intervention aimed at reducing EDCs exposure based on behavioural sciences. Given the trial is currently in progress, no outcome data have been collected yet and no results are reported in this publication. The main aim of the paper is both conceptual and methodological: emphasising the need to go beyond education to induce behaviour change in relation to EDCs exposure and provide an example of a theory-informed intervention.

Routes of exposure

Human biomonitoring studies repeatedly report wide presence of EDCs in human bodies across various regions in the world.[15] People are exposed to EDCs from multiple sources, including environmental pollution (air,[16,17] water[18–20] and soil[21]), but also through consumer products, including food.[22,23] Early life is a vulnerable period, as exposure begins as early as the peri-conceptional and prenatal periods (through the placenta),[24] and postnatally, through breast milk and food.[25] Modifiable exposure is broadly understood as a behavioural or environmental factor that is measurable and modifiable by individuals, communities, or governments.[26] For example, bisphenols are added to plastics to improve physical, thermal and mechanical properties of the product. Even if the use of bisphenol A in food contact materials was banned in the EU, substitutes are commonly found in water bottles, food containers, and can leach into their contents.[27,28] An important dermal exposure to bisphenols is often attributed to thermal paper – receipts; and more recently, clothes made from synthetic textiles.[29] Phthalates are plasticizers added to plastics to increase flexibility and resistance to high temperatures and to achieve the same properties, to personal care products (to reduce cracking of nail polish, avoid stiffness in hairsprays or as fragrance retainers).[30] Per- and polyfluoroalkyl substances (PFAS) are persistent EDCs used in water and stain-free surfaces like non-stick cookware, water-repellent clothing, stain-resistant fabrics and carpets, fast-food wrapping paper; and for smoothing effect in cosmetics.[31] Compounds that affect the endocrine system are frequently present in pesticides, as well as in their residues found in conventionally farmed crops and animal-derived foods. Ultra-processed foods are particularly high in these compounds due to processing, packaging, and formulation.[3] Flame retardants also represent a significant source of EDCs exposure, and their use has increased in parallel with the rising production and consumption of synthetic textiles.[32]

Studies have shown that not everybody has the same level of exposure and suggest it can contribute to explain disparities in health outcomes between racial/ethnic groups or according to the level of income notably.[33,34] For example, Llanos et al. showed that personal care product use varied between females and males, and by ethnicity.[35] Govarts et al.[15] reported that exposure differed strongly depending on socioeconomical status and geographical location.

Reducing exposure through behaviour change

Addressing risk factors associated with EDCs requires multifactorial interventions.[36] One important approach is to reduce exposure through behaviour change. Individuals can make choices about the type of bottle they use to drink water, how frequently they ventilate their homes, or whether to use certain cosmetics, such as nail polish or perfume. Of course, people also depend on the types of products offered on the market.[37,38] Therefore, regulatory and industrial actions are essential to reduce EDCs exposure. However, when several options are available, it remains that individuals must be willing to choose EDCs-free products, and beyond willingness, they need to be able to maintain these changes in their

consumer habits in the long term. Those notions of willingness and capacity refer to important determinants of behaviour, which have been studied for a long time in psychology.

Evidence-based models of behaviour change

Since the 1950s, scientists have studied what predicts behaviour. Early work from behaviourists explains that the future likelihood of a behaviour depends on the consequences (positive or negative) that the person experiences when engaging in that behaviour.[39] Theories aiming to explain human behaviour later evolved to include not only external influences, but also internal ones, such as the perceived capability of performing a behaviour,[40,41] beliefs about the consequences of the behaviour, perceived approval by others and intention.[41,42] Other theories focused on the perceived health threat as a motivator for adopting health behaviours,[43,44] suggesting that someone will perform a health protective behaviour if they believe they are vulnerable to a threat, perceive the threat as severe, and that they are capable of adopting a protective behaviour. However, reviews and meta-analyses show that threat-related variables do not predict behaviour well.[45–49]

Models later evolved to include explanations about the process from intention to do something to the actual realisation of the behaviour.[50] The importance of both motivational (preceding the decision to act) and volitional (following the decision) phases for behaviour change were demonstrated in a meta-analysis.[51]

Other models focus on the importance of the context explaining that behaviour is shaped by multiple interconnected levels, ranging from the individual to the policy.[52] In the case of children's behaviour, models have considered specific influences, notably the fact that the decision of the action is often not the responsibility of the child, instead they are often asked/required by the adults to do specific behaviours.[53]

This review of various models illustrates that even in the very early models of behaviour, information has never been considered sufficient to change behaviour successfully. Figure 1 illustrates schematically the process from information to behaviour change, incorporating findings from several behaviour change models.

Nevertheless, despite being insufficient, information and knowledge can still be necessary. Greyson and Johnson[54] showed how information is included in many of the models of behaviour. According to their analysis, beliefs about the consequences of the behaviour are constructed, at least in part, based on received information, and information can raise awareness of the need for change. In particular, information and knowledge may be needed for issues that people are not yet knowledgeable about. On the topic of EDCs, surveys and qualitative studies among various groups (students, pregnant women, and adults from the general population) indeed show that people lack knowledge about what EDCs are and the associated risks.[55–59] Correlational studies on the level of knowledge about EDCs and health behaviour showed mixed results: some report no significant association,[60,61] while another study showed that this association varied depending on the substances.[62] Knowledge about parabens was associated with more avoidance of chemicals in personal care and household products, but this was not the case for lead: lead was the most widely recognized substance, but the least avoided.[62]

Lifestyle interventions to reduce EDCs exposure

Reviews show that policy interventions (using natural experiment study design to test substances bans effects), as well as interventions that provide low-chemical personal care products,[63] plastic-free foodware, organic food, or fresh food to the intervention group compared to canned food for the control group,[64] succeed in reducing the levels of chemicals measured among participants. However, controlled consumption studies attribute a passive role to participants and do not reflect real life conditions in which individuals have to make choices. This limitation is underlined in the review by Park *et al.*,[65] showing that only four studies among the ones reviewed let participants choose themselves alternative goods or food. In addition, among the 12 interventions reviewed, half lasted less than ten days,[65] failing to assess temporal dynamics of behaviour change. The review by Sieck *et al.*[64] further indicates that educational and lifestyle interventions have more uncertain effects on measured chemical levels than policy measures and studies in which participants' consumption is controlled. Moreover, in the two reviews cited,[64,65] interventions are not analyzed in terms of theoretical framework of behaviour change. Thus, only a limited number of intervention studies have specifically tested, based on a theoretical background, how to promote long-term, voluntary change of habits in relation to reducing EDCs exposure.

Studies focusing on knowledge and risk-awareness illustrate that it is not sufficient for inducing behaviour change. A first example is the PREVED -Pregnancy, PreVention, Endocrine Disruptors- study is an example of a workshop-based intervention study designed to reduce EDCs exposure in pregnant women, with a focus on canned food consumption.[66] The intervention focused on knowledge and risk perception, and the study sample size was 230, participants being for the majority born in Metropolitan France, and in a no precarious situation. Results showed that it failed to significantly change behaviour as in both control and intervention group there were similar proportion of participants whose consumption of canned food and drinks decreased, increased and remained stable. However, risk perception scores

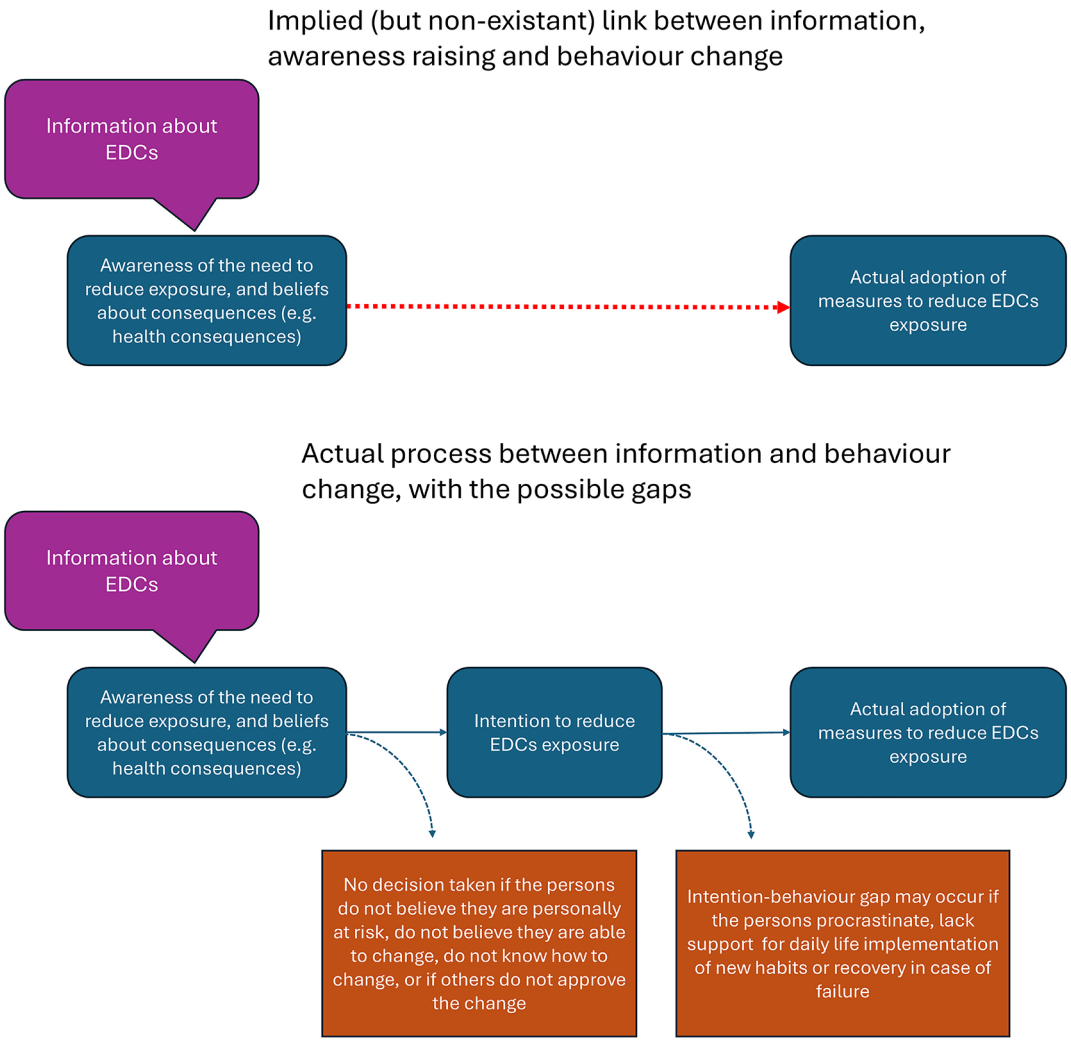

Figure 1. Schematic representation of the process between provision of information and the eventual resulting change in behaviour. The gaps mentioned (in orange) are illustrative and not exhaustive of all possibilities. EDCs = Endocrine Disrupting Chemicals.

increased significantly in the intervention group. A second example is a study using biomonitoring as a technique to motivate exposure reduction.[67] The participating women (N = 135), nearly-half of them self-identified as Black/African American, received a personalized report mentioning either their individual chemical exposure levels, or exposure levels aggregated at the study level. Results were mixed: out of 15 behaviours, only four evolved in a positive direction (fewer food prepared using nonstick cookware; fewer microwave popcorn, and fewer use of a problematic dental floss; and more frequently having added or removed an item from the home due to concern about chemicals), the frequency of ten behaviours did not change, and one protective behaviour (damp-wiping dust) decreased at follow-up. Whether the biomonitoring report was individual or aggregated did not influence the results.

A few studies including techniques besides information provision showed positive effects on behaviour. The first one showed that an education program for Korean pregnant women, informing them about the effects of toxicants and providing strategies to practice protective behaviours, was successful in inducing behaviour change among participants exposed to the intervention (N = 40, compared to 56 in the control group), effect size Cohen's $d = 0.83$ [1].[68] However, a significant limitation of this study is the short timeframe of the evaluation: the post-test occurred four weeks after the intervention ended. Given the time it takes to develop new habits (range between 18 to 254 days according to Lally et al.[69]), studies with longer time frames are needed to properly evaluate implementation of changes in daily lives. The

[1]Effect size calculated using https://www.psychometrica.de/effect_size.html based on the means and standard deviation reported in the paper.

study by Park and Chung, which targeted a cognitive bias that leads to consider oneself as less at risk than the average others, showed success in increasing protective behaviours in a sample of 140 young women.[70] The intervention group was exposed to several behaviour change techniques (BCTs), including self-checking one's habits of exposure, an information session, assessing barriers to reduce exposure, and signing a health contract. Protective behaviours against EDCs included daily life habits such as consuming instant food from convenience stores and using disposable cups for example. The comparison of the evolution in the control group compared to the experimental group show an effect size of $d = 1.29$ [2].Their positive result is thus not surprising, as the intervention targeted a variety of psychological determinants and was not limited to providing knowledge. However, its quasi-experimental design and the lack of biological samples analyses reduce the reliability of these findings.

The mix-methods pilot study by Tsui et al.[71] provides a proof of methodological principle regarding an intervention developed with the community on the use of phthalate-free hair care products among pregnant Women of Color (mostly Hispanic, Black Hispanic, and Black non-Hispanic). The intervention, based on the Environmental Health Literacy framework[72] contained educational video, but also practical tips to reduce exposure. Tools to check product ingredient and alternative, less-toxic products were suggested to participants. The effect of the intervention was assessed through progression in the stages of change, and with urine samples collection. Qualitative data suggest a progression in the stages (moving from "never heard of EDCs, nor EDCs in hair care products" prior the intervention to "having decided to reduce their use of hair care products containing phthalates" and "having limited use of such products" after the intervention) and a reduction of phthalate metabolite concentrations.

A review by Martin *et al.*[73] of lifestyle interventions to reduce EDCs exposure among men and women in their reproductive age conclude on three key elements: 1) tailored education about how to avoid EDCs with interactive educational materials including question/answer option, 2) support and monitoring by counselors or peer discussion group to provide feedback and encouragement, 3) understand individual sources of exposure (through diaries for example) to provide replacement options for items known to contain EDCs.

Example of an awareness-raising campaign in Belgium

As part of the Belgian National Action Plan on Endocrine Disruptors (NAPED, 2022–2026), aiming to raise awareness in vulnerable population groups (pregnant women, women planning pregnancy, young children (0–3 years), and adolescents), public awareness campaigns are planned. These campaigns are coordinated by the Federal Public Service Health, in close collaboration with regional and community authorities. It serves as an example of a public health intervention designed to increase awareness and knowledge of endocrine disruptors.

In May 2024, the first campaign, targeting pregnant women, was launched. It combined the delivery of practical, accessible advice with simple, everyday recommendations tailored to reduce exposure in daily life with a targeted digital communication strategy. Dissemination was based on strong partnerships and leveraged digital channels such as Meta, YouTube, Pinterest, and optimised web content through search engine optimisation.

Healthcare professionals were engaged during the campaign through an informative email, which invited them to download a specially developed Q&A document on EDCs. They were also given the opportunity to order promotional materials, such as postcards and posters, via the Federal Public Service website. In total, over 80,000 postcards and 16,500 posters were ordered and distributed to more than 1,300 healthcare professionals and institutions. A second campaign is planned for November–December 2025. It will broaden outreach to include caregivers of young children (0–3 years) while reinforcing key messages aimed at pregnant women and their partners.

An external evaluation, conducted by a polling institute before and after the campaign among a representative sample of 1,000 Belgians, revealed a generally positive reception, with an average satisfaction score of 7.3/10 overall, rising to 8.0/10 among pregnant women. Knowledge about EDCs increased by 7 percentage points, and the campaign generated widespread interest among both professionals and the general public.

However, despite these encouraging results, self-reported behavioural changes were limited. While participants expressed greater awareness, behavioural changes remained gradual. This highlights a common challenge in health promotion: while a one-off information campaign can effectively raise awareness and improve knowledge, it is rarely sufficient to produce sustained behaviour change.

[2]Effect size calculated using https://www.psychometrica.de/effect_size.html based on the means and standard deviation reported in the paper.

The HYPIEND behaviour change interventions

In the HYPIEND project, two multicomponent interventions have been designed with the aim of accompanying pregnant women and parents of prepubertal children to reduce their daily life exposure to EDCs. The interventions consist of a digital tool and a set of workshops. Moreover, a school-wide educational program based on explicit teaching of healthy behaviors and positive reinforcement and a plastic-free canteen will be implemented in the participating schools.

A reduction in EDCs exposure is expected through targeting the following categories of behaviour: Indoor air quality (e.g., ventilation, avoiding products with fragrances, choice of cleaning products, cleaning dust); choice of food (e.g., avoiding ultraprocessed food, fast-food, canned food and drinks and food with preservatives; favour organic when possible); food preparation (wash fruits and vegetables before eating and peel when relevant); food contact materials (to store, cook and consume); personal care products (choice of products, limit use of products); choice of clothing, furniture, toys and electronics; child's behaviour (wash the baby/child's hands after playing and before eating; for the perinatal study: do not allow to chew certain things; for the prepubertal study: have the child use a stainless steel bottle to drink); gardening and Do It Yourself activities; smoking; and occupational exposure (for the perinatal study only). Major targeted compounds are pesticides, bisphenols, PFAS, phthalates, parabens, benzophenones, flame retardants, PAHs, heavy metals, and isoflavones (the latter, for the prepubertal study only).

Both interventions rely on the Health Action Process Approach (HAPA).[50] This model was chosen because it is more comprehensive than alternative frameworks and does not treat intention as the sole predictor of behaviour. It clearly distinguishes between the motivational and volitional phases, emphasising how intentions are translated into action It is known that around one out of two decisions that individuals take will not be acted upon.[74] In the study by Harley et al.,[63] the main reason for participants' lack of compliance with the furnished low-chemical personal care products alternatives to theirs regular products was forgetting. This result highlights the importance of the volitional phase of behaviour change. For this reason, the HYPIEND interventions not only inform participants about what EDCs are and their potential impact but also inform them about changes that can be made at the individual level and contain techniques such as planning to help people implement their intentions. Those techniques are taken from a 93-techniques list, the BCTs Taxonomy.[75] The use of this taxonomy was dictated by the need of having an extensive choice of techniques to broadly cover behaviour change mechanisms. In addition, using techniques from the taxonomy allows to report the intervention ingredients in a standardized way, improving replicability for future interventions.[75] The appropriate techniques were selected using the Theory and Technique Tool, a related tool helping to identify relevant techniques based on empirical evidence. Participants from the control group will receive a booklet (also distributed to the intervention group) containing information about what EDCs are, and recommendations to reduce exposure, without any additional BCT.

Through the digital tool, participants are able to work on different missions aimed at minimizing exposure to EDCs. By selecting these missions successively, they receive frequent recommendations, tips and motivational quotes that help them to accomplish the selected mission. Some of the BCTs included in the digital tool are: graded tasks, used to increase task self-efficacy (i.e., initiate the change); action planning and problem solving, used to help intenders become actors; and providing tools to conserve mental resources, to increase maintenance self-efficacy (i.e., once the change starts and needs to become a habit).

Another tool used in the HYPIEND interventions is motivational interviewing.[76] It is an interviewing strategy to help the person resolve ambivalence to change, and trigger motivation emerging from within, by letting the person themselves evoke the arguments instead of the counsellor providing them. In the workshops, the animator will provide a brief education about EDCs and spend most of the session using motivational interviewing techniques in group, to help participants build a strong motivation to change. Figure 2 illustrates how the digital tool and the workshops target the HAPA constructs, with examples of BCTs used for each construct. For the perinatal study, group size range between 2 and 8 participants, and maximum 25 parents for the prepubertal study.

Lifestyle interventions must consider the broader social–ecological context, including family dynamics.[77] For example, evidence shows that partner involvement in maternal health promotes healthier behaviours within households,[78] which is particularly relevant for reducing EDCs exposure, a process often requiring collective family action.[73] Yet, most interventions still focus solely on mothers.[79] Including partners in EDCs-related intervention studies is therefore essential for several reasons: it reflects the shared biological responsibility for reproductive health, it acknowledges the social and behavioural dynamics of households, and it allows interventions to target both partners to improve efficacy. Couple-based interventions are particularly well-suited for modifying shared behaviours,[77] such as food choices, product use, or environmental exposures at home, which are often difficult to change in isolation. For this reason, the HYPIEND intervention with pregnant women include the cohabiting partner, and the HYPIEND study on prepubertal children

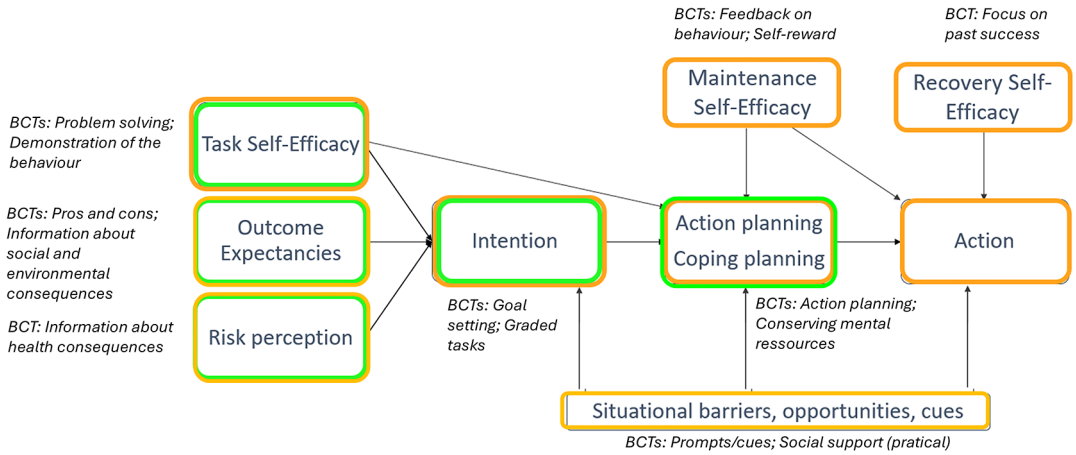

Figure 2. HAPA model, adapted from Schwarzer[39] to reflect which components of the model are targeted through which HYPIEND intervention aspect (workshops = green, digital tool = orange).

includes the whole family and the school through the School Wide Positive Behavioural Interventions and Supports (SWPBIS).

SWPBIS is a multi-tiered intervention designed to positively reinforce students' expected behaviours at school.[53] It aims to create a positive and secure school climate by explicitly teaching and positively reinforcing expected behaviours. These are defined beforehand in observable terms and explicitly taught to students. SWPBIS insists on the sense of adopting a behaviour ("Why" is it important to adopt a specific behaviour at school) and it asks teachers to model the expected behaviour ("How" to perform this behaviour). It is implemented throughout the whole school by all adults supervising the children. The effects of SWPBIS have been documented in several systematic reviews.[80–82] Sugai and Horner's[53] model of positive behaviour support has been revisited and adapted to the context of the HYPIEND project (Figure 3).

Based on the needs and observations of school stakeholders, health-related behaviours will be identified and explicitly taught at the school level or within the classes involved in the project. The behaviours taught and promoted in schools for children are adapted to their autonomy level, and do not require any purchase (e.g. handwashing, ventilating rooms, washing fruit and vegetables, etc.). To support the adoption of these behaviours, strategies such as positive reinforcement and re-teaching sessions will be implemented. Reinforcement will be supported by the school-family partnership, the

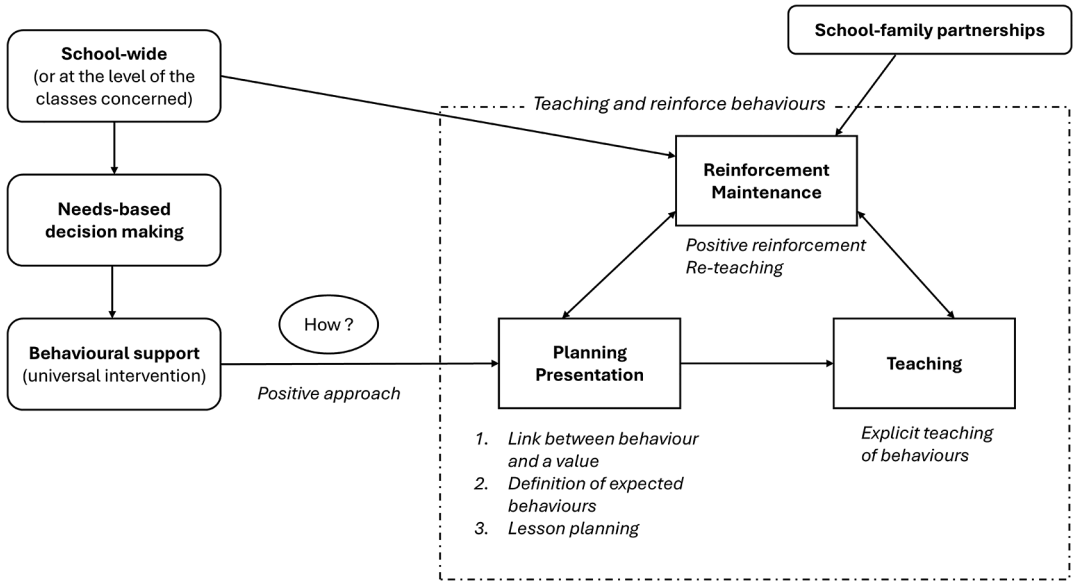

Figure 3. Model for supporting positive health behaviours among students as part of the HYPIEND project.

actions carried out at the whole-school level, and the planning and instructional phases. The positive reinforcement provided by the primary caregiver that we use in schools is likely to encourage the child to adopt and sustain the desired behaviours over time. Several theoretical frameworks can be drawn upon to explain this. According to the systematic review by Kwasnicka et al.,[83] the maintenance of behaviours over time can be explained in particular either by changes in habits (behaviours which have become habitual and are supported by automatic responses to relevant cues) or by the social motivation provided by the social environment (a supportive environment and social support are important for the maintenance of behavioural change. People tend to maintain behaviour that is in line with relevant social changes). Finally, the work of Deci and Ryan[84] allows to formulate the hypothesis that social support (i.e. positive reinforcement from a significant adult in our case) facilitates the internalisation of motivation.

Taking actions to reduce EDCs exposure is not necessarily accessible in the same way to all socioeconomic groups. Some recommendations to avoid EDCs involve buying more costly alternatives (e.g. labelled products). However, in order to prevent generating a feeling of helplessness among participants with low-income, we emphasize solutions that can be adopted by everyone at no cost, such as ventilating the home, washing hands, use homemade all-purpose cleaners, or reducing the number of cosmetics products use. In order to avoid exacerbating inequities, it is important to consider the social determinants of health.[85] In the HYPIEND project, this means including the social factors such as the partner and the whole family, but also the environmental dimension through the school-level intervention. Notably, the Positive Behavioural Interventions and Supports (PBIS) program adapted in the HYPIEND project has a history of being used to improve learning and social outcomes for children in low-income families and neighbourhood.[86]

The effectiveness of the HYPIEND interventions will be tested through a) a tricentric Randomized Controlled Trial (RCT) involving pregnant women and their infants up to 18 months of age in Spain, Belgium and Poland, and b) a bicentric RCT carried out at primary schools from Spain and Belgium for 28 months, targeted to prepubertal children and their parents. Through these RCTs we will evaluate the potential effectiveness of the multicomponent interventions to reduce the internal concentration of several EDCs families. We will further evaluate whether the anticipated reduction in exposure to EDCs can mitigate their potential adverse effects on growth, neurodevelopment, and pubertal maturation. To elucidate the biological mechanisms underlying EDCs-related health outcomes, we will conduct comprehensive analyses of hypothalamic-pituitary axis hormones, cytokines, epigenetic modifications (DNA methylation), gene expression profiles, and gut microbiota composition. Both studies include four measurement times. For the perinatal study the visits are planned at the following dates: V1 (pre-intervention) at 6–11 weeks of pregnancy, V2 at 28–32 weeks of pregnancy, V3 at 4–7 weeks post-delivery; V4 at 12 months post-delivery. For the prepubertal study, the visits are Month 1 (pre-intervention), Month 16, Month 22, Month 34. In both studies, urine, blood and feces are collected at V1 and V4. For the perinatal study, the offspring will be included in the measurements starting at V3. In terms of behaviour change, we will measure both the psychological determinants of behaviour using a HAPA questionnaire, and EDC-related lifestyles habits through a self-report questionnaire. We hypothesize that the intervention group will demonstrate an increase in the HAPA components, as well as a reduced exposure to EDCs. For the control group, we do not expect a significant difference overtime. Given the study design, it will not be possible to assess the effectiveness of each individual intervention component. For future work, the multiphase optimization strategy (MOST) offers a structured way to test ingredients.[87] The complete details on the RCTs protocols will be published shortly through specific papers, while the protocols for the perinatal and the prepubertal studies can already be found respectively here: https://clinicaltrials.gov/study/NCT07142447 and here https://clinicaltrials.gov/study/NCT07411001.

Recommendations and conclusion

As stated by Davis *et al.*,[14] understanding behaviour is necessary for interventions to have the greatest possible impact. However, despite this existing scientific knowledge about human behaviour, an idea remains among some health professionals and policy makers[88–90]: ignorance is the problem, and education a straightforward solution.[89] Simis *et al.* mentions in their essay that an information deficit model persists because of the "lure of rationality"[89 p.400] - the appealing but flawed notion that humans are primarily rational beings who will make logical choices once they are properly informed. This idea is attractive because it simplifies complex behavioural issues into a solvable knowledge gap, allowing experts to assume that mere education alone can change behaviour. However, as mentioned above, human decision-making is influenced by a range of psychological and social factors that go beyond rational analysis.

According to Lippke and Ziegelmann, several reviews and meta-analyses showed that a majority of behavioural interventions reported no theoretical background.[91] We support the call in advocating an improvement in the quality of behaviour change interventions by relying on evidence-based models,[14,91] and advocate that this should also be the case for the field of EDCs.

This paper illustrates a research project mobilizing behaviour change techniques to reduce EDCs exposure at the individual level. However, this should not be considered as putting the responsibility on individuals themselves. On the contrary, the message is to urge the scientific community, health professionals and policy-makers to make better public health interventions on this topic. In addition to communication, other policy categories are also essential to have a stronger and lasting impact, such as legislation, service provision and regulation.[92] The ENKORE [3] policy brief[93] calls for actions such as revisions of relevant EU regulation for a better protection of consumers and moving beyond chemical-by-chemical assessment approach to better reflect real-life exposure. In this context, behavioural approach could be useful to improve the impact of structural measures: for example. Lentz et al. showed that support for public policies such as meat taxes, plant-based food subsidies, and increasing the availability of plant-based meal in public institutions could be explained by respondents' beliefs.[94] Given that political will often depends on public support,[95] it is important to consider individual-level perspective even for structural measures.

To conclude, given the important health and environmental adverse effects of these substances, any attempt to change behaviours regarding exposure to EDCs should be carefully crafted to increase the chances of maximum efficacy. So that EDCs-related interventions have the best possible chance on being effective both biologically and behaviourally, they must be tailored and holistic, actively involve the broader social environment and go beyond education and awareness by incorporating concrete and evidence-based BCTs. These elements are crucial to enhance motivation, engagement, and adherence, ultimately maximize the probability of improving outcomes in both research and practice.

Ethics and consent

Ethical approval and consent were not required.

Data availability

Extended data

Appendix are uploaded on Zenodo.

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Version 2

Reviewer Report 10 August 2026

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✓ **Dede Teteh-Brooks**
UT MD Anderson Cancer Center, Houston, Texas, USA

Bravo to the authors for the improvements made on the manuscript. The revisions are appropriate and I approve this version for indexing. Best wishes on your implementation efforts.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health disparities, equity informed community-based intervention, environmental exposures in personal care products, CBPR

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 27 July 2026

https://doi.org/10.21956/openreseurope.25567.r77480

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✓ **Jasmine McDonald**
Columbia University Irving Medical Center, New York, New York, USA

The authors did a great job in responding to my comments. I have no further comments with the exception of the below. I vote to Accept the manuscript for indexing.

Re: #6. Discuss a successful cohabitation intervention?
Answer: we are not familiar with “cohabitation intervention”, could you please clarify what you

mean by that?

I was speaking about those living in the same household being impacted by a chemical exposure reduction intervention.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)
Yes

Does the article adequately reference differing views and opinions?
Yes

Are all factual statements correct, and are statements and arguments made adequately supported by citations?
Yes

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Breast Cancer; Molecular Epidemiology; Environmental Exposures

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 24 July 2026

https://doi.org/10.21956/openreseurope.25567.r77483

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Moses O Alfred
Redeemer's University, Ede, Nigeria
Oyedolapo Bamigboye
Ilishan-Remo, Babcock University School of Basic and Applied Sciences (Ringgold ID: 309474), Ede,

Ogun State, Nigeria

Authors have sufficiently addressed all issues raised in the revised document. The manuscript is significantly improved for indexing.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Water Quality Monitoring; Water Treatment; Evidence-based policy engagement; Environmental quality monitoring; CO2 conversion; climate

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 24 July 2026

https://doi.org/10.21956/openreseurope.25567.r77481

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Robb Shawe
Capitol Technology University,, Laurel, Maryland, USA

I have reviewed the revisions and determined that the author has successfully adhered to the recommendations provided.

V/r

Dr. Robb Shawe

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Environmental Health & Exposure Science, Behaviour Change Science & Health Psychology, Public Health Intervention Design, Risk Communication & Health Communication, Systems Thinking & Social-Ecological Models, and Occupational and Environmental Safety Regulation

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 28 February 2026

https://doi.org/10.21956/openreseurope.23544.r68703

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Jasmine McDonald
Columbia University Irving Medical Center, New York, New York, USA

The article by Moussaoui and colleagues describes the current interventions involving pregnant women and interventions involving pubertal children. The authors then go on to describe their own intervention, HYPIEND - a multilevel intervention for pregnant women and children designed using the HAPA and Theory and Technique behavioral tool. I have several comments to strengthen the papers utility to the environmental health and intervention community:

Introduction:
1. Given pregnant persons and children will be discussed, the opening paragraph regarding routes of exposure should include breast milk and placenta.

2. Re: Lifestyle interventions: Are these all relevant studies for pregnant women and children?
- The author should detail the demographics of the articles discussed/included given the Open Letter's focus on vulnerable populations.
- Overall, greater descriptions of studies and outcomes (including magnitude) would be helpful; for example, the PREVED and report-back study could use more detail. For example, how many women in PREVED, what were the four behaviors evolving into a positive direction and is this lesson learned incorporated into HYPIEND? Do the authors deem report-back unimportant thus not included in HYPIEND and what/how/when was information reported back relative to change assessment?
- There is also the NY-based studies in pregnant women that is not mentioned (citation below).
- Moreover, depending on the age cut-off for pubertal children, there is also the HERMOSA study (citation below).
- Discuss a successful cohabitation intervention?

Model Clarity
Within the discussion of evidence based models, the models used in past studies are not named - or are they non-existent. Limitations are noted, but not the theory of behavior applied to invoke change.

Study Length
- Authors note a limitation in past studies in the length of time. While I agree sustainable behaviors require a longer view - what is long? Many EDCs have short half-lives and change can be observed within days - especially for phthalates (please see the HERMOSA study among adolescents). How do authors define long-term behavioral or the formation of a habit?

HYPIEND Study Design
- The HYPIEND project fails to describe action steps if replacement items are not affordable or unavailable.
- Figure 2, does this model translate for pregnant women and children?

- Figure 3, how does child-based/school-based behavioral maintenance occur? Through what autonomy? Many children do not have purchasing or selection autonomy; therefore, how will efficacy be promoted in SWPBIS?
- How large should groups be during motivational interviewing? Are children involved?
- Greater detail on EDC-related biological health outcomes and source/medium used to assess - urine, blood, from whom? frequency? pre-/post-?

References

1. Harley K, Kogut K, Madrigal D, Cardenas M, et al.: Reducing Phthalate, Paraben, and Phenol Exposure from Personal Care Products in Adolescent Girls: Findings from the HERMOSA Intervention Study. *Environmental Health Perspectives*. 2016; **124** (10): 1600-1607 Publisher Full Text
2. Tsui F, Vilfranc C, Llanos A, Houghton L, et al.: Hair care product use among pregnant women of color: protocol for a feasibility educational intervention. *Frontiers in Reproductive Health*. 2026; **7**. Publisher Full Text
3. Vilfranc C, Houghton L, Tsui F, Barrett E, et al.: The hair tales of women of color in Northern Manhattan: a qualitative analysis. *Frontiers in Reproductive Health*. 2024; **6**. Publisher Full Text

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)

Partly

Does the article adequately reference differing views and opinions?

Yes

Are all factual statements correct, and are statements and arguments made adequately supported by citations?

Yes

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)

Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Breast Cancer; Molecular Epidemiology; Environmental Exposures

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 07 Apr 2026

Lisa Moussaoui

We thank the reviewer for the valuable comments and explain below how we addressed each of them.
The article by Moussaoui and colleagues describes the current interventions involving pregnant women and interventions involving pubertal children. The authors then go on to describe their own intervention, HYPIEND - a multilevel intervention for pregnant women and children designed using the HAPA and Theory and Technique behavioral tool. I have several comments to strengthen the papers utility to the environmental health and intervention community:

Introduction:
#1. Given pregnant persons and children will be discussed, the opening paragraph regarding routes of exposure should include breast milk and placenta.
Answer: Thank you for this relevant comment, we now mention breast milk and placenta as routes of exposure p.6 l.51-53.

#2. Re: Lifestyle interventions: Are these all relevant studies for pregnant women and children?
- The author should detail the demographics of the articles discussed/included given the Open Letter's focus on vulnerable populations.
Answer: Not all studies cited included pregnant women or children participants, however given the scarcity of studies on the topic we decided to cite even interventional studies that included non-vulnerable population. We now have added more demographics details to the study we cite when the information is available (for PREVED:, p.8 l.155-157; Boronow et al,. study: p.8 l.161-163, Kim et Jeong study: p.9 l.172, Tsui et al. p.9 l.194-195). For the study by Park and Chung, no details were provided on the population besides being young women.

#3. Overall, greater descriptions of studies and outcomes (including magnitude) would be helpful; for example, the PREVED and report-back study could use more detail. For example, how many women in PREVED, what were the four behaviors evolving into a positive direction and is this lesson learned incorporated into HYPIEND? Do the authors deem report-back unimportant thus not included in HYPIEND and what/how/when was information reported back relative to change assessment?
Answer: To answer this comment we calculated effect sizes (cohen’s d, based on means and SD reported in the papers) in order to give the reader a better estimate of the outcome's magnitude (p.9 l.175-176, and p.9 l.187-188). The sample sizes were also included. Regarding the Boronow et al. study, we now specify in the text the four behaviours that evolved in the positive direction (p.8 l.165-l.167). This result was not directly incorporated

into HYPIEND given that the intervention techniques were very different. We did not include report-back in our intervention because this specific technique did not emerge in our intervention conception logic (using the HAPA constructs and then using the theory and technique tool). This does not mean we judge the technique unimportant. It is the same as for comparative optimism in Park and Chung study, that resulted in a positive outcome, but we did not include it because it did not fit our theoretical framework. In addition to the logic of the intervention construction, we were also very careful to avoid triggering too much anxiety in our participants, both from vulnerable groups. Biofeedback might trigger anxiety, and the effect of fear on behaviour change has been debated a lot in the literature (see e.g. Kok et al. 2017, https://doi.org/10.1080/17437199.2017.1415767).

#4. There is also the NY-based studies in pregnant women that is not mentioned (citation below).
Answer: Thank you for informing us about this recent publication, we added it in the text p.9 l.192-203.

#5. Moreover, depending on the age cut-off for pubertal children, there is also the HERMOSA study (citation below).
Answer: the cut-off age for prepubertal children is lower, but we included the HERMOSA study in the paper as it provides an example of controlled consumption intervention study for personal care products and the reduction of chemicals in urine (p.8 l.135-13), and also highlight the challenges to behaviour change even when the products are provided (p.11 l.267-270).

#6. Discuss a successful cohabitation intervention?
Answer: we are not familiar with “cohabitation intervention”, could you please clarify what you mean by that?

#7. Model Clarity
Within the discussion of evidence based models, the models used in past studies are not named - or are they non-existent. Limitations are noted, but not the theory of behavior applied to invoke change.
Answer: we purposefully did not mention names of the theoretical models in the section “evidence-based models of behaviour change” following a reviewer’s comment in a previous round that it was “the alphabet soup of the behavioral change models”, and decided to focus on the theoretical concepts rather than the theories themselves to make this part more accessible to a broad readership. Because the theories themselves were not introduced in this section, we decided to not mention them later in the paper as they were not previously defined.

#8. Study Length
- Authors note a limitation in past studies in the length of time. While I agree sustainable behaviors require a longer view - what is long? Many EDCs have short half-lives and change can be observed within days - especially for phthalates (please see the HERMOSA study among adolescents). How do authors define long-term behavioral or the formation of a habit? **Answer:** Our study focus is not on the immediate observation of changes in biological samples responding to change of products as it has been done in other studies,

but rather in the feasibility for families to implement real change of everyday behaviours in an uncontrolled context (e.g. without replacement products provided.) For this reason, we rely on the work by Lally and al. to define the length of habit formation (range between 18-254 days). We now explicit this length in the text p.9 l.178.

#9. HYPIEND Study Design
- The HYPIEND project fails to describe action steps if replacement items are not affordable or unavailable.
Answer: no replacement items are provided in the HYPIEND study. However, in the intervention materials, especially the digital tool messages, there are tips for participants on how to solve those barriers of price or availability. Those tips belong to the problem solving behaviour change technique (mentioned p.11 l.285). The exact content of the messages will be the topic of another publication.

#10. Figure 2, does this model translate for pregnant women and children?
Answer: figure 2 aims to illustrate the theoretical model used to build the intervention. However, the translation for participant is presented in the theory of change tables that are now present in appendix

#11. Figure 3, how does child-based/school-based behavioral maintenance occur? Through what autonomy? Many children do not have purchasing or selection autonomy; therefore, how will efficacy be promoted in SWPBIS?
Answer: The child has no choice in school indeed, as it is the teachers who consult with one another to select behaviours based on feasibility, the needs in a particular school and our recommendations. That said, the positive reinforcement provided by the primary caregiver that we use in schools is likely to encourage the child to adopt and sustain the desired behaviours over time. Several theoretical frameworks can be drawn upon to explain this. According to the systematic review by Kwasnicka et al. (2016), the maintenance of behaviours over time can be explained in particular either by changes in habits (behaviours which have become habitual and are supported by automatic responses to relevant cues) or by the social motivation provided by the social environment (a supportive environment and social support are important for the maintenance of behavioural change. People tend to maintain behaviour that is in line with relevant social changes). Finally, the work of Deci and Ryan (2000) allows to formulate the hypothesis that social support (i.e. positive reinforcement from a significant adult in our case) facilitates the internalisation of motivation. With regard to purchases, the behaviours taught and promoted in schools for children do not require any purchase (e.g. handwashing, ventilating rooms, washing fruit and vegetables, etc.). We now mention this in the text p.13 l. 331-333 and l.336-346.

#12. How large should groups be during motivational interviewing? Are children involved?
Answer: Children are not involved in the workshops. For the prepubertal study the workshops take place in the evening at school, similarly to regular school-parents meeting. Group size vary a lot depending on the number of parents participating in the study in one school, the maximum is 25 parents. For the perinatal study, groups range between 2 and 8 participants and depends on the number of participants at that time in the intervention arm and available for that specific workshop. We do not have any theory-based recommendation on how large groups should be. The range of group size is now

mentioned p.12 l.297-298

#13. Greater detail on EDC-related biological health outcomes and source/medium used to assess - urine, blood, from whom? frequency? pre-/post-?
Answer: We now briefly describe EDC-related biological outcomes p.13-14 l.370-375. Given that the aim of the paper is to provide a conceptual commentary on behaviour change interventions, and that there will be separate publications for the study protocols, we limited the provided information to a summary of the measurement points and main outcomes.

Competing Interests: No competing interests were disclosed.

Reviewer Report 19 February 2026

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Dede Teteh-Brooks
UT MD Anderson Cancer Center, Houston, Texas, USA

Summary of review:
This manuscript addresses an important challenge in EDC exposure reduction by advocating for evidence-based behavior change models rather than information-only approaches. The HYPIEND and SWPBIS project may potentially support vulnerable stakeholders dwelling in European and other countries given the dearth of behavioral interventions available. However, the paper has significant clarity and presentation issues that make it difficult to follow and understand the interventions being proposed.
Key Issues:

- Several paragraphs are lacking references to support statements. Include references to support key claims throughout the manuscript.
  - For example: statements about EDCs representing 'a threat for the ecosystem and human health' (page 1), claims that 'current attempts to reduce modifiable exposure often rely on knowledge provision and awareness-raising campaigns' (page 1), and assertions about the transition from awareness to behavior change not being 'straightforward' (page 1) all need supporting references.
- Unclear manuscript identity and purpose. As discussed by previous reviewers the inclusion of a narrative literature review, conceptual framework and protocol description is creating confusion on the intended primary purpose of the manuscript.
  - Recommendation: Shorten the narrative review and provide a protocol description of the two interventions
- Intervention components and distinctions are unclear. The introduction of the two interventions with their components are not distinct in the current presentation.

        - Recommendation: Provide a summary table of each components side-by-side.
        - Suggested narrative structure**;** for each intervention, present separately: Introduction of the interventions; Development process including theories, models, and frameworks; study design - protocol
    - Evaluation of implementation components. The manuscript describes multicomponent behavioral interventions but does not specify which implementation strategies or frameworks will be used to test and evaluate the distinct components, making it unclear how the effectiveness of individual intervention elements will be assessed.
    - Highlighting two comments from previous reviewers that should be included in manuscript revisions:
        - Organization and presentation of narrative review, framework, and protocol
        - Equity and accessibility considerations: will the populations with highest EDC exposures benefit from these interventions?

Overall Assessment:
While this paper addresses an important topic, the current presentation makes it difficult to understand the interventions and their relationships. Clearer organization, better headings, and comprehensive referencing are needed to make this work accessible and impactful.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)
Yes

Does the article adequately reference differing views and opinions?
Partly

Are all factual statements correct, and are statements and arguments made adequately supported by citations?
Partly

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Health disparities, equity informed community-based intervention, environmental exposures in personal care products, CBPR

I confirm that I have read this submission and believe that I have an appropriate level of

expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 07 Apr 2026

Lisa Moussaoui

We thank the reviewer for the valuable comments and explain below how we addressed each of them.

Summary of review:

This manuscript addresses an important challenge in EDC exposure reduction by advocating for evidence-based behavior change models rather than information-only approaches. The HYPIEND and SWPBIS project may potentially support vulnerable stakeholders dwelling in European and other countries given the dearth of behavioral interventions available. However, the paper has significant clarity and presentation issues that make it difficult to follow and understand the interventions being proposed.

Key Issues: Reviewer's comment #1: Several paragraphs are lacking references to support statements. Include references to support key claims throughout the manuscript. For example: statements about EDCs representing 'a threat for the ecosystem and human health' (page 1), claims that 'current attempts to reduce modifiable exposure often rely on knowledge provision and awareness-raising campaigns' (page 1), and assertions about the transition from awareness to behavior change not being 'straightforward' (page 1) all need supporting references.

Answer: We have added references to support those sentences (for “statements about EDCs representing 'a threat for the ecosystem and human health” p.5 l.17 and for “assertions about the transition from awareness to behavior change not being 'straightforward'” p.5 l.34). For the claim that “current attempts to reduce modifiable exposure often rely on knowledge provision and awareness-raising”, to our knowledge there is no scientific publication stating this. This sentence is an observation from our reading of the literature and also professional experience with campaigns such as the example in Belgium described in the paper. We acknowledge that this might be an insufficient answer to the comment and added a sentence and a reference to illustrate how information and awareness-raising is argued as being the solution to change individuals' exposure to EDCs (p.5 l.28-33).

Reviewer's comment #2: Unclear manuscript identity and purpose. As discussed by previous reviewers the inclusion of a narrative literature review, conceptual framework and protocol description is creating confusion on the intended primary purpose of the manuscript. Recommendation: Shorten the narrative review and provide a protocol description of the two interventions

Answer: We thank you for the recommendation. We do not feel that shorten the narrative review would be appropriate because we believe it’s an important part of the open letter. However, to address this comment and similar ones from other reviewers, we clarified the identity of the manuscript (p.5-6 l.42-l.46). The protocol of the interventions are the object of separate publication, however in order to clarify the content of the intervention we added a theory of change in appendix

Reviewer's comment #3: Intervention components and distinctions are unclear. The

introduction of the two interventions with their components are not distinct in the current presentation. Recommendation: Provide a summary table of each components side-by-side. Suggested narrative structure; for each intervention, present separately: Introduction of the interventions; Development process including theories, models, and frameworks; study design – protocol
Answer: We followed the recommendation to include a theory of change of the interventions, and created one for each intervention to make it clearer between perinatal and prepubertal (see appendix)

Reviewer's comment #4: Evaluation of implementation components. The manuscript describes multicomponent behavioral interventions but does not specify which implementation strategies or frameworks will be used to test and evaluate the distinct components, making it unclear how the effectiveness of individual intervention elements will be assessed.
Answer: The added theory of change schema aims to clarify the content of the intervention. Regarding the test of the individual intervention elements, unfortunately the study design will not allow such evaluation, given we have only one intervention group exposed to the intervention packaged, compared to the control group. We now mention this as a limitation and refer to multiphase optimization strategy (MOST) for future studies p.14 l.380-382.
Highlighting two comments from previous reviewers that should be included in manuscript revisions:

Reviewer's comment #5: Organization and presentation of narrative review, framework, and protocol
Answer: We clarified the aim of the paper (an opinion letter), theory of change, and refer to protocol papers.

Reviewer's comment #6: Equity and accessibility considerations: will the populations with highest EDC exposures benefit from these interventions?
Answer: We included a discussion on equity p.13 l.347-358.

Competing Interests: No competing interests were disclosed.

Reviewer Report 19 February 2026

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Robb Shawe
Capitol Technology University,, Laurel, Maryland, USA

Full Reviewer Report

The manuscript addresses an important gap in environmental health intervention design by integrating behavioural science into EDC exposure-reduction strategies. The authors successfully demonstrate that knowledge-only approaches are insufficient and provide a compelling rationale for multicomponent, theory-driven interventions.

Strengths

- Clear articulation of the problem and rationale.
- Comprehensive review of behavioural models.
- Balanced discussion of successful and unsuccessful interventions.
- Strong justification for including partners, families, and schools.
- Well-structured presentation of HYPIEND as an illustrative model.

Major Points Requiring Revision

1. **Clarify the manuscript's primary contribution.**
   Explicitly state that this is a conceptual/methodological Open Letter, not an empirical evaluation.
2. **Avoid implying the demonstrated effectiveness of HYPIEND.**
   Use conditional or future-oriented phrasing consistently.
3. **Provide a brief justification for selecting HAPA and BCT Taxonomy** over other behavioural frameworks.
4. **Strengthen the causal logic of the intervention.**
   A theory-of-change table or paragraph would improve clarity.
5. **Address equity considerations.**
   Discuss how socio-economic constraints may affect the feasibility of recommended behaviours.
6. **Clarify that behavioural interventions complement—not replace—policy and regulatory actions.**

Minor Points

- Expand summaries of key studies to include population and scope.
- Correct typographical errors ("informationsession", "unclearer effects").
- Consider adding an appendix listing key EDCs referenced.
- Ensure global—not only EU—context is acknowledged.

Conclusion

The manuscript is scientifically sound and makes a valuable contribution. With the revisions outlined above—particularly clarifying the manuscript's purpose, strengthening the causal logic, and refining the language regarding expected outcomes—it will be well-positioned for indexing.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)

Yes

Does the article adequately reference differing views and opinions?

Yes

Are all factual statements correct, and are statements and arguments made adequately supported by citations?

Partly

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
Yes

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Environmental Health & Exposure Science, Behaviour Change Science & Health Psychology, Public Health Intervention Design, Risk Communication & Health Communication, Systems Thinking & Social-Ecological Models, and Occupational and Environmental Safety Regulation

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 07 Apr 2026

Lisa Moussaoui

The manuscript addresses an important gap in environmental health intervention design by integrating behavioural science into EDC exposure-reduction strategies. The authors successfully demonstrate that knowledge-only approaches are insufficient and provide a compelling rationale for multicomponent, theory-driven interventions.
Strengths

- Clear articulation of the problem and rationale.
- Comprehensive review of behavioural models.
- Balanced discussion of successful and unsuccessful interventions.
- Strong justification for including partners, families, and schools.
- Well-structured presentation of HYPIEND as an illustrative model.

Major Points Requiring Revision

1. Clarify the manuscript's primary contribution.

Explicitly state that this is a conceptual/methodological Open Letter, not an empirical evaluation.

Answer: we agree that this was unclear and now explicitly state the main contribution of the paper p.5-6 l.44-46.

1. Avoid implying the demonstrated effectiveness of HYPIEND.

Use conditional or future-oriented phrasing consistently.

Answer: we reformulated the sentences that were confusing about the demonstrated effectiveness (p.5 l.36; p.10 l.242-243; l.249; p.13 l.363-364; p.15 l.420-421, l.425)

1. Provide a brief justification for selecting HAPA and BCT Taxonomy over other behavioural frameworks.

Answer: we added justification for the choice of the HAPA (p.11 l.262-266 and l.267-270) and BCT taxonomy (p.11 l.274-278)

1. Strengthen the causal logic of the intervention.

A theory-of-change table or paragraph would improve clarity.

Answer: A theory of change is now present in appendix.

Address equity considerations. Discuss how socio-economic constraints may affect the feasibility of recommended behaviours.
Answer: we added a section on socio-economic inequities p.13 l.347-358.

Clarify that behavioural interventions complement—not replace—policy and regulatory actions.

Answer: we clarified p.14 l.404-l.417 that behavioural interventions do not mean replacing other types of actions and putting the responsibility on individuals.

Minor Points

- Expand summaries of key studies to include population and scope.

Answer: we now mention sample size and caracteristics of participants in the studies we describe p.8 and 9

- Correct typographical errors ("informationsession", "unclearer effects").

Answer: we did not find the “Informationsession” typos, in our manuscript it appears as two separate words. We did replace “unclearer effects” by “more uncertain effects” p.8 l.144-145.

- Consider adding an appendix listing key EDCs referenced.

Answer: we now cite in the paper the list of targeted compounds p.11 l.259-261.

- Ensure global—not only EU—context is acknowledged.

Answer: we now broaden the geographical scope of the problem (p.5 l.13-l.16)

Conclusion The manuscript is scientifically sound and makes a valuable contribution. With the revisions outlined above—particularly clarifying the manuscript's purpose, strengthening the causal logic, and refining the language regarding expected outcomes—it will be well-positioned for indexing

Answer: we thank the reviewer and hope our modifications matches his expectations

Competing Interests: No competing interests were disclosed.

Reviewer Report 10 February 2026

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Moses O Alfred
Redeemer's University, Ede, Nigeria
Oyedolapo Bamigboye
Ilishan-Remo, Babcock University School of Basic and Applied Sciences (Ringgold ID: 309474), Ede, Ogun State, Nigeria

Reviewers' comments:
This manuscript addresses an important and timely challenge: the persistent reliance on information-based approaches to reduce exposure to endocrine-disrupting chemicals (EDCs), despite strong behavioural science evidence that knowledge alone is insufficient to drive sustained behaviour change. By integrating established behavioural models and illustrating their application through the HYPIEND project, the authors make a valuable contribution to intervention design and policy-oriented environmental health research. The manuscript is conceptually sound and well aligned with its stated objectives. However, several aspects of framing, structure, and language would benefit from clarification to ensure that readers clearly understand the paper's conceptual and methodological nature, its intended contribution, and the boundaries of the claims being made.
The comments below are intended to strengthen the manuscript without altering its core message.

1. The manuscript currently sits between a narrative review, a conceptual framework paper, and a project description. While this hybrid approach is acceptable, the manuscript does not explicitly state its primary contribution, which may lead to misinterpretation by readers expecting empirical results. I suggest that authors explicitly state in the Introduction that the manuscript is a conceptual and methodological contribution aimed at improving the design of EDC exposure-reduction interventions from the behavioural science perspective.
2. Authors are to clarify that HYPIEND is presented as an illustrative, theory-informed intervention model, not as an evaluated or completed trial.
3. Several sections use language that may be interpreted as implying demonstrated effectiveness (e.g., "able to reduce exposure" or "effective interventions") despite the absence of outcome data. It is suggested that authors use conditional or forward-looking phrasing (e.g., "is designed to," "is expected to," "will be evaluated") when referring to intervention outcomes except where there is sufficient empirical evidence for the conclusion.
4. Authors are to systematically revise the language to clearly distinguish between evidence-based (behavioural theory, prior intervention research) and the expected outcomes of HYPIEND.
5. Although multiple behavioural models are discussed and applied, the rationale for selecting specific frameworks (e.g., HAPA) over others is sometimes implicit. Briefly justify the selection of key behavioural models (e.g., HAPA, BCT taxonomy).

6. The manuscript presents many components of the HYPIEND intervention, but the causal logic linking psychological determinants to behaviour change and exposure reduction is not always explicit. Add a concise theory-of-change description (textual or tabular) that links psychological determinants, behaviour change techniques, behavioural outcomes and reduced exposure. This will enhance internal coherence and make the intervention logic more accessible to practitioners and policymakers.
7. While the manuscript acknowledges regulatory and environmental determinants of exposure, the emphasis on individual and social behaviour could be misinterpreted as shifting responsibility away from structural actors. Explicitly state that behavioural interventions are complementary to regulatory, industrial, and policy-level actions, not substitutes. In addition, authors should discuss how behavioural approaches can enhance the effectiveness of structural measures (e.g., improved compliance, adoption, and risk communication).
8. Equity considerations are mentioned but not fully developed, despite their relevance to behavioural interventions. The manuscript could be improved with a brief discussion of differential capacity to adopt recommended behaviours across socioeconomic groups and of how theory-driven interventions can be adapted to reduce inequities rather than exacerbate them.
9. “unclearer effect” in line 12, paragraph 1 page 5 could be substituted with an alternative word that would make the statement/point clear for readers.
10. Additional information (probably as an appendix of supporting documents) on some identified EDCs may further enhance the robustness of the manuscript
11. Authors referred to some studies but over-summarized them, for example, for statements like “Results showed that it failed to significantly change behaviour”, the scope of the study (population) and the extent to which the study failed could be included to bring context to the discussion and aid comparison.
12. Edit the typo „informationsession“ in paragraph 3 (last line), page 5
13. The scope (reference) of EDCs in the environment could be extended to all global regions

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)

Yes

Does the article adequately reference differing views and opinions?

Yes

Are all factual statements correct, and are statements and arguments made adequately supported by citations?

Partly

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)

Yes

Where applicable, are recommendations and next steps explained clearly for others to

follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Water Quality Monitoring; Water Treatment; Evidence-based policy engagement; Environmental quality monitoring; CO2 conversion; climate

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.

Author Response 07 Apr 2026

Lisa Moussaoui

This manuscript addresses an important and timely challenge: the persistent reliance on information-based approaches to reduce exposure to endocrine-disrupting chemicals (EDCs), despite strong behavioural science evidence that knowledge alone is insufficient to drive sustained behaviour change. By integrating established behavioural models and illustrating their application through the HYPIEND project, the authors make a valuable contribution to intervention design and policy-oriented environmental health research. The manuscript is conceptually sound and well aligned with its stated objectives. However, several aspects of framing, structure, and language would benefit from clarification to ensure that readers clearly understand the paper's conceptual and methodological nature, its intended contribution, and the boundaries of the claims being made.
The comments below are intended to strengthen the manuscript without altering its core message.

- We thank the reviewers for their precise and constructive recommendations. Below we detail how we address each point.

#1 The manuscript currently sits between a narrative review, a conceptual framework paper, and a project description. While this hybrid approach is acceptable, the manuscript does not explicitly state its primary contribution, which may lead to misinterpretation by readers expecting empirical results. I suggest that authors explicitly state in the Introduction that the manuscript is a conceptual and methodological contribution aimed at improving the design of EDC exposure-reduction interventions from the behavioural science perspective.

Answer: We agree that the first version of the manuscript was at the crossroads between several types of papers. We now explicitly state that the primary contribution is conceptual and not experimental (p.5-6 l.44- 46)

#2 Authors are to clarify that HYPIEND is presented as an illustrative, theory-informed intervention model, not as an evaluated or completed trial.

Answer: The HYPIEND project is now more clearly presented as a trial in progress with no

experimental data available at this time and presented for an illustrative goal. (p.5 l.41-44)

#3 Several sections use language that may be interpreted as implying demonstrated effectiveness (e.g., “able to reduce exposure” or “effective interventions”) despite the absence of outcome data. It is suggested that authors use conditional or forward-looking phrasing (e.g., “is designed to,” “is expected to,” “will be evaluated”) when referring to intervention outcomes except where there is sufficient empirical evidence for the conclusion.

Answer: We reformulated the sentences that were misleading about the experimental evidence (p.5 l.36; p.13 l.363; p.15 l.420-421, l.425)

#4 Authors are to systematically revise the language to clearly distinguish between evidence-based (behavioural theory, prior intervention research) and the expected outcomes of HYPIEND.

Answer: We corrected instances of unclear wording (in the abstract, twice “evidence-based”; p.10 l.242-243; l.249; p.13 l.363-364)

#5 Although multiple behavioural models are discussed and applied, the rationale for selecting specific frameworks (e.g., HAPA) over others is sometimes implicit. Briefly justify the selection of key behavioural models (e.g., HAPA, BCT taxonomy).

Answer: the use of BCT taxonomy is now justified in the text (p.11 l.274-278), as well as the HAPA framework (p.11 l.262-266 and l.267-270).

#6 The manuscript presents many components of the HYPIEND intervention, but the causal logic linking psychological determinants to behaviour change and exposure reduction is not always explicit. Add a concise theory-of-change description (textual or tabular) that links psychological determinants, behaviour change techniques, behavioural outcomes and reduced exposure. This will enhance internal coherence and make the intervention logic more accessible to practitioners and policymakers.

Answer: we added in appendix a theory-of-change schema for each study to explicit the causal logic of our project

#7 While the manuscript acknowledges regulatory and environmental determinants of exposure, the emphasis on individual and social behaviour could be misinterpreted as shifting responsibility away from structural actors. Explicitly state that behavioural interventions are complementary to regulatory, industrial, and policy-level actions, not substitutes. In addition, authors should discuss how behavioural approaches can enhance the effectiveness of structural measures (e.g., improved compliance, adoption, and risk communication).

Answer: we thank the reviewers for this comment and confirm that it would be a misinterpretation of our paper to consider it as putting responsibility on individuals. This paper was written in the context of a policy brief (now cited p.14 l.410) aiming to urge

professionals and policy makers to design better communication on EDCs. In order to avoid misinterpretation of our paper, we now mention regulatory and industrial actions p.6 l.83-84 as essential. We also stress in the discussion that the point of the paper is not to put responsibility on individuals and mention other types of policy categories p.14 l.404-412. We discuss how behavioural approach can support or impede other types of measures effectiveness p.14 l.412-417.

#8 Equity considerations are mentioned but not fully developed, despite their relevance to behavioural interventions. The manuscript could be improved with a brief discussion of differential capacity to adopt recommended behaviours across socioeconomic groups and of how theory-driven interventions can be adapted to reduce inequities rather than exacerbate them.

Answer: We now discuss equity considerations in more depth, p.6 l.72-77 (in terms of inequity in exposition to EDCs), and p.13 l.347-358 (for inequity in access to alternatives). #9 “unclearer effect” in line 12, paragraph 1 page 5 could be substituted with an alternative word that would make the statement/point clear for readers.

Answer: we reworded this sentence for better clarity (p.8 l.144-145)

#10 Additional information (probably as an appendix of supporting documents) on some identified EDCs may further enhance the robustness of the manuscript

Answer: We now specify the list of compounds that are included in the HYPIEND project p.11 l.259-261

#11 Authors referred to some studies but over-summarized them, for example, for statements like “Results showed that it failed to significantly change behaviour”, the scope of the study (population) and the extent to which the study failed could be included to bring context to the discussion and aid comparison.

Answer: We now describe more in details the studies cited in the paper p.8 l.155-157, l.162, p.9 l.172, l.175, l.182. More specifically, we mentioned the sample size for each study, described more clearly the results of the PREVED study, and calculated effect sizes for the two studies described as successful for comparative purposes.

#12 Edit the typo „informationsession“ in paragraph 3 (last line), page 5

Answer: Unfortunately, we did not find the typo in the paper, and wonder if it is a problem of display depending on the software in which the manuscript was open?

#13 The scope (reference) of EDCs in the environment could be extended to all global regions

Answer: Thank you for this comment. We had to shorten the paper for a previous submission and focused on EU data, but we definitely agree that it is a global issue. We have now extended the geographical scope of the introduction (p.5 l.13-16)

Competing Interests: No competing interests were disclosed.

Reviewer Report 06 February 2026

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Mukaddes T Miral
Istanbul Kültür University, Istanbul, Turkey

The article is a comprehensive study targeting groups at risk for endocrine disruptors, emphasizing that education alone is insufficient for creating behavioral change and discussing the necessity of interventions such as motivational interviewing in addition to education. However, in terms of content, it gives the impression of being somewhere between a review and a protocol study. Following a long introduction and a detailed literature review, two study protocols, HYPIEND and SWPBIS, are introduced; however, the aims, scope, and methods of these protocols are not sufficiently clear.
It is not explicitly stated whether the main purpose of the study is to present two study protocols or to defend the hypothesis that "education alone is insufficient for behavioral change against endocrine disruptors." Furthermore, it is known that most existing studies in the literature also demonstrate that education alone is insufficient and suggest different interventions. Therefore, the original contribution of this study needs to be more clearly presented.
The article notes that previous studies are insufficient because they focus primarily on information transfer; however, the proposed HYPIEND and SWPBIS protocols also appear to be largely based on similar approaches. The protocol does not clearly define which interventions (training, motivational interviewing, role modeling, etc.) will be implemented, which measurement tools will be used for evaluation, and what kinds of results are expected after the intervention.
Accordingly, it is suggested that the introduction and literature review sections be shortened; and that the structure of the protocol, planned interventions, expected outcomes, and evaluation methods be presented in a clearer, more systematic, and simpler language. This would make the purpose, scope, and scientific contribution of the study more understandable.

Is the rationale for the Open Letter provided in sufficient detail? (Please consider whether existing challenges in the field are outlined clearly and whether the purpose of the letter is explained)
Partly

Does the article adequately reference differing views and opinions?
Yes

Are all factual statements correct, and are statements and arguments made adequately

supported by citations?
Yes

Is the Open Letter written in accessible language? (Please consider whether all subject-specific terms, concepts and abbreviations are explained)
Partly

Where applicable, are recommendations and next steps explained clearly for others to follow? (Please consider whether others in the research community would be able to implement guidelines or recommendations and/or constructively engage in the debate)
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: endocrine disruptors, women's health, adolescent health, reproductive health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 07 Apr 2026

Lisa Moussaoui

We thank the reviewer for the valuable comments and explain below how we addressed each of them.

Reviewer's comment #1: The article is a comprehensive study targeting groups at risk for endocrine disruptors, emphasizing that education alone is insufficient for creating behavioral change and discussing the necessity of interventions such as motivational interviewing in addition to education. However, in terms of content, it gives the impression of being somewhere between a review and a protocol study. Following a long introduction and a detailed literature review, two study protocols, HYPIEND and SWPBIS, are introduced; however, the aims, scope, and methods of these protocols are not sufficiently clear.
It is not explicitly stated whether the main purpose of the study is to present two study protocols or to defend the hypothesis that "education alone is insufficient for behavioral change against endocrine disruptors." Furthermore, it is known that most existing studies in the literature also demonstrate that education alone is insufficient and suggest different interventions. Therefore, the original contribution of this study needs to be more clearly presented.

Answer: We agree that the original version of the manuscript was unclear in its contribution. Following suggestion from several reviewers, we now more clearly state in the introduction that the paper aims to provide a conceptual discussion of what is needed to trigger behaviour change in order to reduce the exposition to EDCs, and give an illustration of a trial in progress based on theory (p.5-6, l.42-46). We would like to clarify that both presented studies fall within the HYPIEND project. The SWPBIS is one of the theoretical

frameworks used in the study design, along with the HAPA and motivational interviewing. Finally, we agree that the literature already show that education alone is insufficient, this is exactly the point of the paper: to make readers aware that evidence exist on the need to go beyond mere information provision. We thought that such point needed a publication, not for a researcher audience (because the field is already aware), but for a wider public such as policy-makers and professionals, because it continuously seems that despite this scientific knowledge, many communication campaigns continue to be merely information provision (not only on EDCs but on many other health topics and broader). It might be useful to inform that this paper was published in relation to a policy brief common to the cluster of projects associated with HYPIEND (now cited p.14 l.410).

Reviewer's comment #2: The article notes that previous studies are insufficient because they focus primarily on information transfer; however, the proposed HYPIEND and SWPBIS protocols also appear to be largely based on similar approaches. The protocol does not clearly define which interventions (training, motivational interviewing, role modeling, etc.) will be implemented, which measurement tools will be used for evaluation, and what kinds of results are expected after the intervention.
Accordingly, it is suggested that the introduction and literature review sections be shortened; and that the structure of the protocol, planned interventions, expected outcomes, and evaluation methods be presented in a clearer, more systematic, and simpler language. This would make the purpose, scope, and scientific contribution of the study more understandable. **Answer:** We included a theory of change schema to clarify the structure of the intervention (in appendix). Regarding measurement tools, it is not the intention of this paper to provide the details of the study protocol (in terms of outcomes and evaluation methods), since this is going to be published in specific papers with regards to the study protocols. However, we clarified that we expect a positive change in the intervention group, and no change in the control group p.14 l.378-380

Competing Interests: No competing interests were disclosed.