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**Original Article**

# Neurobehavioral Performance of Estate Residents with Privately-Treated Water Supply

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**Abstract**

**Background:** Neurotoxicants present in water supply may affect human functions in terms of attention, response speed and perceptual motor speed. Neurobehavioural performance can be influenced by gender, age and education levels. This study aims to assess the neurobehavioral performance of palm oil estate residents with private water supply in southern Peninsular of Malaysia.

**Methods:** A total of 287 and 246 participants from estates with private (PWS) and public water supply (PUB) were recruited to complete a demographic and subjective symptom questionnaire followed by the Neurobehavioral Core Test Battery (NCTB).

**Results:** PWS participants who consumed privately-treated water performed poorly in all NCTB tests compared to PUB participants except for Santa Ana test. Significant group differences in neurobehavioral performance were found for Digit Span Backward ($P$=0.047), Benton Visual Retention ($P$=0.006) and Trail Making B tests ($P$<0.05); which measures the function of memory, attention and visual perception-conceptual. Gender, age and years of education influenced the NCTB scores ($P$<0.05). Female participants performed poorly in tests measuring latency but excellently tackled those tests that determined association. Younger participants from both PWS and PUB performed better on NCTB tests when compared to other age groups ($P$<0.05). PWS and PUB participants in this study who received a longer duration of education excelled in the NCTB tests ($P$=0.000).

**Conclusion:** Poor neurobehavioral performance is associated with low water supply quality which affects neurofunctions in terms of attention, memory, response and perceptual motor speed.

**Keywords:** NCTB, Neurobehavior, Water quality, Private water supply, Self-treated water

## Introduction

Water in adequate quantity and quality is essential and is a basic human right (1-3). Unsafe water supply, inadequate sanitation and hygiene contributed to about 88% of diarrheal disease. In 2002 alone, 1.1 billion people lacked access to improved water sources, which represented 17% of the global population. Certainly, the high accessibility to water supply not only in urban areas ensures better quality of life (4, 5).

Although access to safe water supply in Malaysia has somewhat improved over the last couple of years, a small percentage of the population is still relying on private water supply. Specifically in Kota Tinggi District in the state of Johor Darul Takzim, 66.7% of estates are still using private water supply as a main source of drinking water (6). These estates are owned by private owners and they are usually located in the rural areas. The public water service covers only part of the district, especially urban areas. The installation of public water pipes is very costly for the private owners of the estates, resorted them to supply the population with the nearest water sources. However, there are plans to upgrade the private water supply to public water supply in the near future. Private water supplies are those supplied by other than government authority and the maintenance rely solely upon the owners (7).Inappropriate treated water may expose the vulnerable water to contaminants such as microbes, heavy metals, pesticides and pathogens which could lead to waterborne disease outbreaks and ill-health (8-11).

A number of studies in Aberdeenshire, UK and Ontario, Canada have shown potential health concerns associated with contaminated private water supply as they receive minimal treatment when compared to the government regulated source (7, 12). Analysis of water quality in selected estates in Kota Tinggi District, Johor, Malaysia showed a failure to meet aluminium (Al) minimum standard (13); the Malaysian National Standard for Drinking Water Quality (NSDWQ) by the Ministry of Health, Malaysia in the private drinking water compared to the public water supply besides other parameters such as pH, turbidity and residual chlorine (14). The NSDWQ issued by the ministry was adopted from the World Health Organization (WHO); Guidelines for Drinking Water Quality (15).

These contaminants from agricultural areas were believed to have the potential to become neurotoxicant agents that affect human neurofunctions by contaminated water consumption. Exposure to pollutants like metals may impair the neurobehavioral development, inducing mental and psychomotor disturbances as well as learning behavioral and sensory disorders (16, 17). Neurobehavioral tests such as the WHO Neurobehavioral Core Test Battery (NCTB) is widely used to assess neurotoxicity exposure besides other test versions such as a computerized evaluation system and Raven Colored Progressive Matrices (RCPM)(18-20). Researchers mainly used NCTB to assess neurobehavioral performance in workers exposed to occupational hazards such as industrial facto-ries (21-24), agriculture areas (25-28) or individuals exposed to prolonged polluted environment through air and water (29-31).

The NCTB test comprised subjective symptom questionnaires and a series of tests that assessed the following functions: attention/response speed, auditory memory, manual dexterity, perceptual-motor speed, visual perception/ memory and motor steadiness. The NCTB is widely used because it is relatively economical, uncomplicated and appropriate battery consisting mainly of paper-and-pencil test, short administration time, not tiring and easy to administer to poorly literate subjects since it measures very basic functions. The battery test was developed for health hazard evaluations and field studies for which the testing time per person is restricted and circumstances do not tolerate the use of more sophisticated methods. It is also to be used as standard indicator tests within larger test batteries to allow cross-comparisons between studies and countries (18, 32).

There are numerous publications reported in the literature regarding human neurobehavioral deficits due to chemical exposure from the occupational settings (33, 34), industrial pollution (35) as well as the unexpected incident that leads to a major damage towards the environment (31, 36). There were also a few research conducted on the voluntarily general population and also on laboratory rats to assess their neurology functions (37-41). However, the health risk assessment relating to the consumption of minimally-treated water supply with the risk of health and neurobehavioral effect has never been reported in the region of Southeast Asia, particularly in Malaysia.

Realizing the fact that private water supply in a previous study (13) is minimally treated and there may be a risk of exposure from neurotoxicants present in the water, this extension study attempts to assess the neurobehavioral performance of estate residents consuming private water supply. The finding of this research will generally provide a baseline data for preparation in developing an environmental health policy towards the implementation of 100% safe water supply in rural areas, specifically in plantation areas; compatible with the Tenth Malaysia Plan which included an objective of enhancing the quality of life of the estates workers (42). The results of this study might support and create an urge to upgrade the water supply in those estates in the near future.

## Materials and Methods

### *Study population*

This cross-sectional study was conducted from 2009 to 2012 in palm oil estates with two types of water supply; private water supply (PWS) or public water supply (PUB). Participants from PWS estates and PUB estates were considered as exposed group and non-exposed group respectively. The sample size was calculated using a formula of $n= [Z^2 p\ (1-p)]\ /\ d^2$ (43,44) with expected percentage of incidence is 76% adopted from the Camelford water incident (31) where a total of 287 and 246 participants from both PWS and PUB were involved. All the participants were either estate workers or residents of the estates who have stayed for at least a year. Only literate Malaysians between the ages of 16 to 65 years were selected.

### *Procedure*

A questionnaire with information sheet and consent form regarding the purpose of the study was given to the participants prior to the administration of the neurobehavioral tests. The questionnaire consisted of data on personal, educational, medical, occupational and exposure to neurotoxicants. The participants were interviewed by trained personnel and examined physically by a medical assistant.

### *Neurobehavioral Core Test Battery (NCTB)*

#### *Subjective symptom questionnaire*

The participants were requested to complete a subjective symptoms questionnaire containing 37 questions which list the most common discomfort in behavior, feeling and sensations that a person may experience prior to the commencement of the NCTB tests as explained below.

#### *Simple Reaction Time*

Simple reaction time (SRT) measures how fast a person reacts and requires sustained attention from the subject. The subjects' task is to give fast motor responses to repetitive visual stimuli in randomly varied intervals of 3, 5 and 7 seconds. The test was measured using Lafayette Simple Reaction Time instrument.

#### *Benton Visual Retention*

The Benton Visual retention test is a test of short term visual memory which utilizes the same geometric patterns and measures the ability to organize geometrical patterns in space and memorize them.

#### *Pursuit Aiming*

The test measures the ability to make quick and accurate movements with the hand. The participants were requested to place one dot inside each circle following the pattern given on the Pursuit Aiming Test sheet.

#### *Digit Symbol*

The Digit Symbol test is a test of perceptual motor speed which also requires learning of association. The Digit Symbol test worksheet contains a list of numbers that are associated with certain simple symbols in a list of random digits from 1 through 9 with blank squares below each digit.

#### *Digit Span*

The Digit Span test is a test of immediate (short term) auditory memory which requires focused attention. It consists of two different parts, Digits Forward and Digit Backward; each comprising seven pairs of progressively longer sequences of random numbers.

#### *Trail-making*

The trail making is a test of visual conceptual and visuomotor tracking which involves motor speed and attention functions. This test was divided into two parts namely Part A and Part B. Both parts consist of 25 circles distributed over a sheet of paper. The participants were asked to draw a line connecting the numbers in ascending order in Part

A, while in Part B, they were requested to connect the circles by alternating numbers and alphabets.

*Santa Ana Manual Dexterity*

The Santa Ana test is a test of manual dexterity which required rapid eye-hand coordinated movements. The equipment consists of a base plate with 48 square holes and equal number of fitted pegs having a cylindrical upper part and square base. The participants were asked to turn each peg 180° as fast as possible in 30 seconds.

### Statistical methods

The statistical analysis was performed with SPSS 20.0 using parametric tests to test for differences between variables. Correlation (Spearman's rho) analysis was used to explore the relationship between variables. We then performed multiple linear regressions for each of the WHO NCTB test scores controlling for gender, age and years of education. All statistical tests were estimated at 95% level of confidence.

## Results

Table 1 shows the summary of demographic characteristics of participants. The response rate for both PWS and PUB was 82% and 67%. All questions were successfully responded by the participants except for one participant who failed to complete the question on the use of a water filter.

### Prevalence of subjective symptoms

A total of 44 and 38 participants from PWS and PUB who were on long-term medication (diabetes, high blood pressure, renal failure) were excluded from the study. The prevalence of significant subjective symptoms among the PWS and PUB participants is shown in Table 2. The most significant symptoms were headache, diarrhea and difficulty walking in the dark ($\alpha$=0.05).

### Neurobehavioral test performances

The means of the outcome variables of the neurobehavioral tests together with *P*-values for the significance tests of group differences are presented in Fig. 1. The PWS participants performed poorly in all NCTB tests (*P*<0.005) compared to PUB participants except for Santa Ana Manual Dexterity II and III.

**Table 1:** Demographic characteristics of participants

| Studied variables | PWS participants (n=287) | PUB participants (n=248) |
|---|---|---|
| **Age (years)** | | |
| Mean (SD) | 39.04 (10.1) | 35.9 (12.0) |
| **Gender** | | |
| Male (%) | 152 (53.0) | 117 (47.6) |
| Female (%) | 135 (47.0) | 129 (52.4) |
| **Ethnic** | | |
| Malay (%) | 284 (99.0) | 216 (87.8) |
| Indian (%) | 3 (1.0) | 30 (12.2) |
| **Education level** | | |
| No education (%) | 2 (0.7) | 1 (0.4) |
| Primary (%) | 82 (28.6) | 72 (29.3) |
| Secondary (%) | 182 (63.4) | 166 (67.5) |
| Diploma (%) | 18 (6.3) | 5 (2.0) |
| Degree (%) | 3 (1.0) | 2 (0.8) |
| **Length of stay (years)** | | |
| Mean (SD) | 10.1 (5.4) | 19.8 (13.8) |
| **Water filter** | | |
| Yes (%) | 60 (20.9) | 38 (15.4) |
| No (%) | 226 (78.7) | 208 (84.6) |
| **Smoking status** | | |
| Smokers (%) | 98 (34.1) | 73 (29.7) |
| Non-smokers (%) | 189 (65.9) | 173 (70.3) |

Significant group differences were found for Digit Span Backward (*P*=0.047), Benton Visual Retention (*P*=0.006), and Trail Making B tests (*P*<0.05).When adjusted for gender, Fig. 2 showed that female PWS participants performed better in Pursuit Aiming test (*P*<0.00) while female PUB participants scored better in Digit Symbol test (*P*=0.002).

Only male PUB participants were found to be faster in Simple Reaction Time (*P*=0.003). Score-wise, both female and male from PUB presented a higher score compared to PWS participants in most of the tests.

On the other hand, different age categories showed different levels of performance.

**Table 2:** Prevalence of subjective symptoms among PWS and PUB participants

| Symptoms | PWS participants (n=246) | | PUB participants (n=287) | | OR (CI) |
|---|---|---|---|---|---|
| Lethargy | 126 | 51.4 | 169 | 59.5 | 1.39 (0.98,1.96) |
| Early morning lethargy | 81 | 33.1 | 110 | 38.6 | 1.27 (0.89, 1.82) |
| Easily fall asleep | 92 | 37.6 | 124 | 43.4 | 1.27 (0.90, 1.80) |
| Sleepy while watching TV | 75 | 30.7 | 83 | 29.1 | 0.93 (0.64, 1.34) |
| Insomnia | 32 | 13.1 | 53 | 18.6 | 1.51 (0.94, 2.44) |
| Sudden awake up at night | 78 | 32.0 | 99 | 34.7 | 1.13 (0.79, 1.63) |
| Bad dream | 15 | 6.1 | 14 | 4.9 | 0.79 (0.37, 1.68) |
| Forgetful | 89 | 36.3 | 114 | 40.0 | 1.17 (0.82, 1.66) |
| Incoherence | 38 | 15.5 | 51 | 18.0 | 1.19 (0.75, 1.89) |
| Daydream | 30 | 12.2 | 43 | 15.0 | 1.27 (0.77, 2.09) |
| Difficulty concentrating | 42 | 17.1 | 68 | 23.9 | 1.53 (1.00, 2.35) |
| Depressed | 21 | 8.6 | 25 | 8.8 | 1.03 (0.56, 1.88) |
| Poor interest | 27 | 11.0 | 24 | 8.5 | 0.75 (0.42, 1.33) |
| Fearful | 28 | 11.4 | 29 | 10.2 | 0.89 (0.51, 1.53) |
| Isolation | 15 | 6.1 | 16 | 5.6 | 0.92 (0.44, 1.89) |
| Irritability | 45 | 18.3 | 52 | 18.2 | 1.00 (0.64, 1.55) |
| Restlessness | 36 | 14.8 | 37 | 13.0 | 0.86 (0.53, 1.41) |
| ***Headache*** | 80 | 32.9 | 119 | 41.9 | **1.47 (1.03, 2.10)** |
| Vertigo | 81 | 33.3 | 103 | 36.7 | 1.16 (0.81, 1.66) |
| Palpitation | 24 | 9.8 | 32 | 11.2 | 1.16 (0.66, 2.03) |
| Excessive sweating | 95 | 38.9 | 106 | 37.3 | 0.93 (0.66, 1.33) |
| Poor appetite | 33 | 13.5 | 50 | 17.5 | 1.37 (0.85, 2.20) |
| ***Diarrhea*** | 6 | 2.4 | 19 | 6.7 | **2. 86 (1.12, 7.27)** |
| Constipation | 16 | 6.5 | 30 | 10.5 | 1.68 (0.89, 3.17) |
| Abdominal colic | 24 | 9.8 | 34 | 12.0 | 1.25 (0.72, 2.17) |
| Finger numbness | 60 | 24.6 | 82 | 28.9 | 1.24 (0.84, 1.84) |
| Upper limb numbness | 30 | 12.2 | 40 | 14.1 | 1.17 (0.71, 1.95) |
| Lower limb numbness | 25 | 10.2 | 35 | 12.3 | 1.23 (0.71, 2.12) |
| Upper limb weakness | 31 | 12.7 | 34 | 11.9 | 0.94 (0.56, 1.57) |
| Lower limb weakness | 23 | 9.4 | 27 | 9.5 | 1.00 (0.56, 1.80) |
| Tremor | 27 | 11.1 | 23 | 8.1 | 0.71 (0.39, 1.27) |
| Easily dropped things | 17 | 6.9 | 10 | 3.5 | 0.49 (0.22, 1.09) |
| ***Difficulty walking in the dark*** | 48 | 19.6 | 88 | 30.9 | **1.83 (1.22, 2.74)** |
| Changing smell sensation | 11 | 4.5 | 13 | 4.6 | 1.02 (0.45, 2.31) |
| Changing taste sensation | 14 | 5.7 | 14 | 4.9 | 0.85 (0.40, 1.82) |
| Facial numbness | 8 | 3.3 | 8 | 2.8 | 0.86 (0.32, 2.31) |
| Facial paraesthesia | 5 | 2.0 | 10 | 3.5 | 1.75 (0.59, 5.20) |

In this study, age of participants was categorized into five different groups. Overall, the PWS participants from the youngest age category (16-25 years) excelled in most of the sub-tests, significantly in five sub-tests out of eleven ($P$<0.014) compared to other age categories (Fig. 3(a)). Similar achievements were shown by the PUB participants from the same age category that significantly did well in three sub-tests (Fig. 3 (b)). However, it is noticeable that participants from the age category of 26 to 35 years did better in Santa Ana for both groups ($P$<0.05).

Level of education may also influence the neurobehavioral performance. When the years of education of the participants were assessed, PWS participants who had 13 to 18 years of education, scored excellently in all tests. Similar findings were observed in PUB participants except for Santa Ana II and III (Fig. 4). For tests that measured latency, better NCTB performance was observed in PWS and PUB participants who had 13-18 years of education except for Simple reaction Time for PUB participants.

Table 3 shows the correlation between age and education level with neurobehavioral test performance for PWS and PUB participants. In PWS, Pursuit Aiming test showed significant moderate correlation with age category while Digit Symbol and Benton Visual Retention test showed moderate correlation with years of education. In PUB, Digit symbol, Pursuit Aiming and Trail Making A and B showed moderate correlation with age category while Digit Symbol and Trail Making B showed moderate correlation with years of education. Multiple regression analyses revealed that age, level of education and gender do have significant contribution to the NCTB scores. The significant contribution of age is towards all NCTB tests except for Digit Span Forward and Santa Ana II while the contribution of education level is towards all NCTB tests as well except for Simple reaction time and Santa Ana II. Gender plays role significantly in Simple reaction time, Digit symbol and Pursuit aiming. Table 4 summarized regression model between those dependent and independent variables.

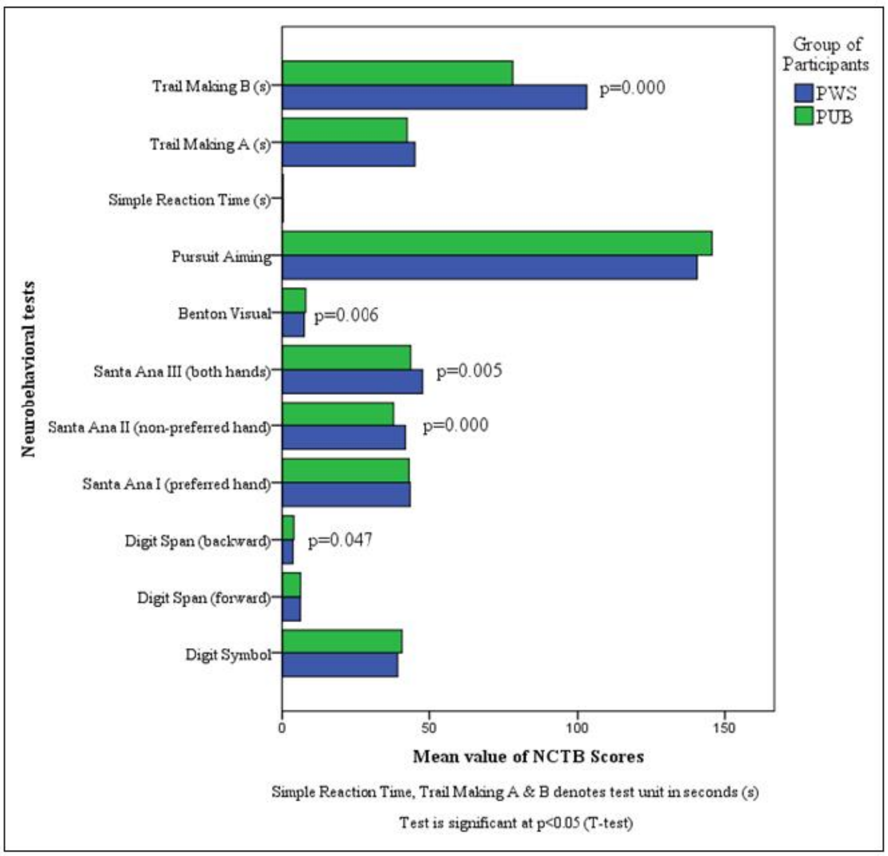


**Fig. 1:** Neurobehavioral performance of PWS participants and PUB participants

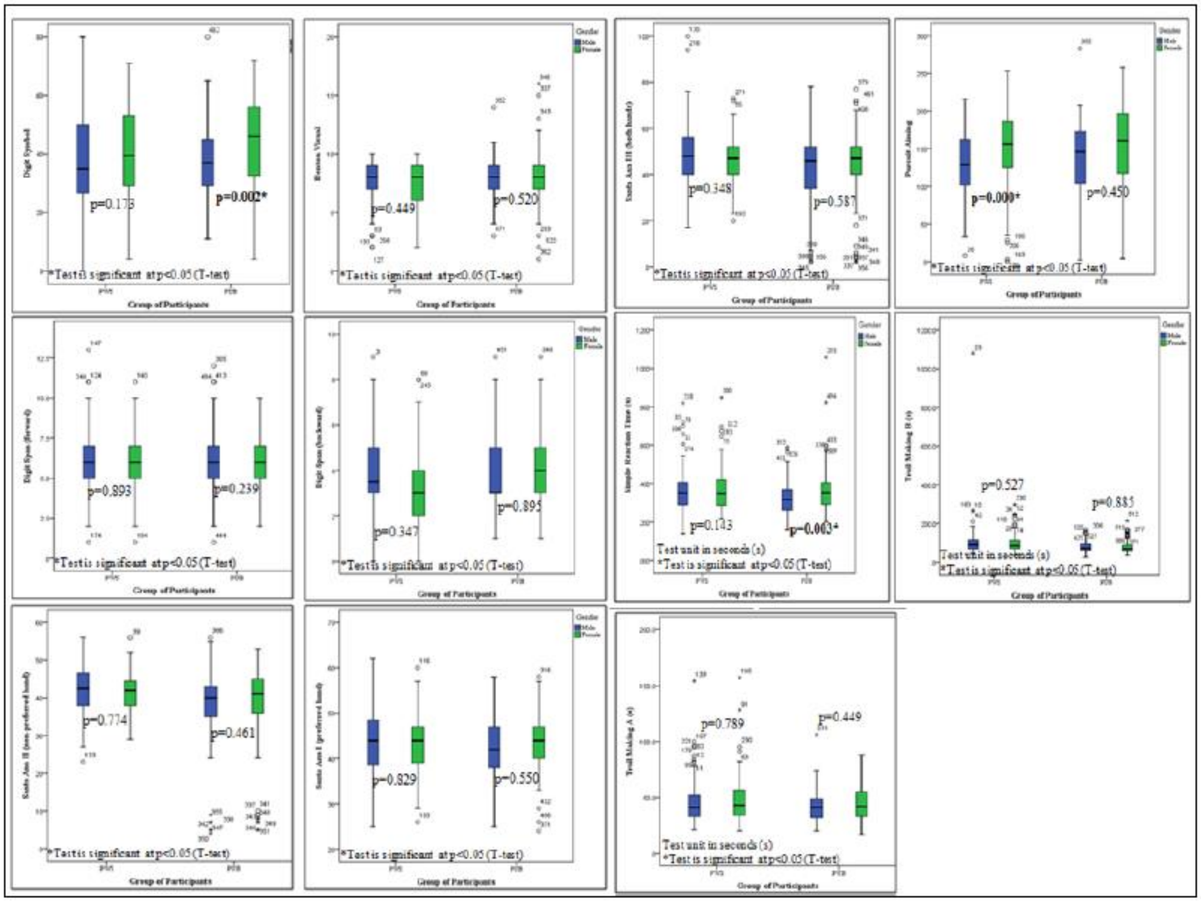


**Fig. 2:** Neurobehavioral performance showed by the males and females of the PWS and PUB participants

**Table 3:** Correlation coefficient of NCTB tests with age category and years of education for PWS and PUB participants

| NCTB Tests | PWS | | PUB | |
|---|---|---|---|---|
| | Age category | Years of Education | Age category | Years of Education |
| Simple Reaction Time | 0.159* | -0.111 | 0.216** | -0.172* |
| Digit Symbol | -0.433 | 0.481** | -0.559** | 0.525** |
| Digit Span Forward | -0.172** | 0.268** | -0.147* | 0.199** |
| Digit Span Backward | -0.290** | 0.349** | -0.201** | 0.262** |
| Santa Ana (preferred hand) | -0.185** | 0.287** | -0.176* | 0.116 |
| Santa Ana Dexterity (non-preferred hand) | -0.219** | 0.262** | -0.134 | 0.088 |
| Santa Ana Dexterity (both hands) | -0.294** | 0.367** | -0.239** | 0.125 |
| Benton Visual Retention | -0.323** | 0.511** | -0.313** | 0.255** |
| Pursuit Aiming Test | -0.462** | 0.370** | -0.550** | 0.353** |
| Trail-Making A | 0.263** | -0.330** | 0.411** | -0.304** |
| Trail-Making B | 0.232** | -0.343** | 0.423** | -0.403** |

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

**Table 4**: Summary of regression analysis for variables of age, education level and gender with each NCTB test

| NCTB Test | Variables | Unstandardized Coefficient | | Standardized Coefficient | t | Sig. | R | R2 | Adjusted R2 | Std Error of the Estimate |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std Error | Beta | | | | | | |
| Simple Reaction Time | Age | .002 | .000 | .181 | 3.675 | **.000** | | | | |
| | Education level | .000 | .009 | -.001 | -.013 | .989 | .279 | .078 | .069 | .106 |
| | Gender | .040 | .010 | .183 | 3.960 | **.000** | | | | |
| Digit Symbol | Age | -.540 | .061 | -.398 | -8.831 | **.000** | | | | |
| | Education level | 8.675 | 1.137 | .322 | 7.632 | **.000** | .615 | .378 | .371 | 11.985 |
| | Gender | 4.280 | 1.246 | .142 | 3.437 | **.001** | | | | |
| Digit Span Forward | Age | -.014 | .010 | -.078 | -1.420 | .156 | | | | |
| | Education level | .727 | .187 | .201 | 3.879 | **.000** | .258 | .066 | .056 | 1.980 |
| | Gender | -.275 | .204 | -.068 | -1.348 | .178 | | | | |
| Digit Span Backward | Age | -.031 | .008 | -.209 | -3.926 | **.000** | | | | |
| | Education level | .710 | .147 | .241 | 4.817 | **.000** | .355 | .126 | .116 | 1.558 |
| | Gender | -.173 | .161 | -.052 | -1.079 | .281 | | | | |
| Santa Ana I | Age | -.090 | .033 | -.152 | -2.769 | **.006** | | | | |
| | Education level | 1.837 | .609 | .156 | 3.019 | **.003** | .267 | .071 | .061 | 6.435 |
| | Gender | .866 | .665 | .065 | 1.302 | .194 | | | | |
| Santa Ana II | Age | -.050 | .042 | -.065 | -1.200 | .231 | | | | |
| | Education level | 1.177 | .785 | .076 | 1.500 | .134 | .310 | .096 | .086 | 8.297 |
| | Gender | .408 | .857 | .024 | .476 | .634 | | | | |
| Santa Ana III | Age | -.234 | .066 | -.190 | -3.547 | **.000** | | | | |
| | Education level | 2.857 | 1.228 | .117 | 2.326 | **.020** | .346 | .120 | .109 | 12.989 |
| | Gender | -1.025 | 1.343 | -.037 | -.763 | .446 | | | | |
| Benton | Age | -.045 | .009 | -.265 | -5.254 | **.000** | | | | |
| | Education level | 1.092 | .161 | .321 | 6.792 | **.000** | .472 | .223 | .214 | 1.698 |
| | Gender | -.302 | .176 | -.079 | -1.716 | .087 | | | | |
| Pursuit Aiming | Age | -1.906 | .212 | -.419 | -8.982 | **.000** | | | | |
| | Education level | 15.686 | 3.963 | .173 | 3.958 | **.000** | .575 | .330 | .322 | 41.897 |
| | Gender | 11.684 | 4.332 | .115 | 2.697 | **.007** | | | | |
| Trail-Making A | Age | .430 | .082 | .274 | 5.231 | **.000** | | | | |
| | Education level | -5.929 | 1.536 | -.190 | -3.861 | **.000** | .392 | .154 | .144 | 16.236 |
| | Gender | 3.053 | 1.684 | .087 | 1.813 | .071 | | | | |
| Trail-Making B | Age | 1.178 | .294 | .213 | 4.003 | .000 | | | | |
| | Education level | -28.641 | 5.502 | -.260 | -5.206 | .000 | .366 | .134 | .124 | 57.786 |
| | Gender | -3.391 | 6.037 | -.027 | -.562 | .575 | | | | |

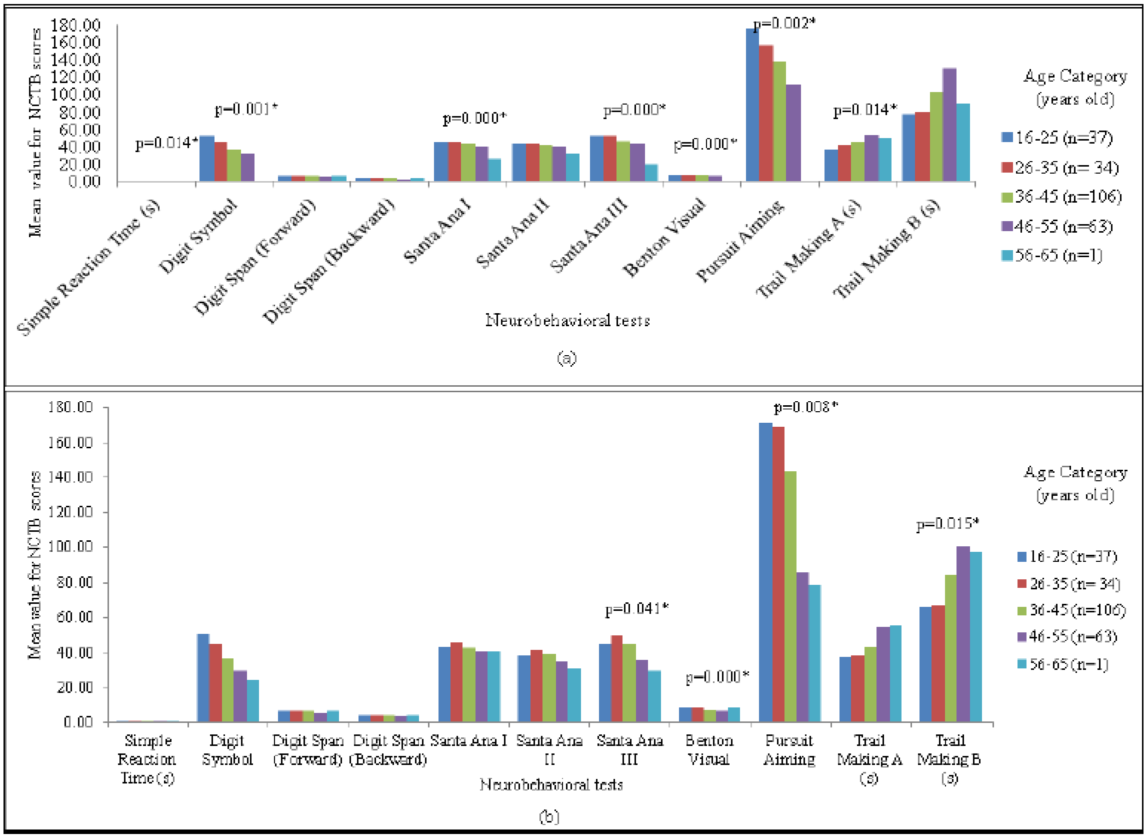


**Fig. 3:** Neurobehavioral performances between the (a) PWS and (b) PUB participants according to the specified age groups. Simple reaction time, Trail making A & B records the marks in seconds (s). Test is significant at *P*<0.05

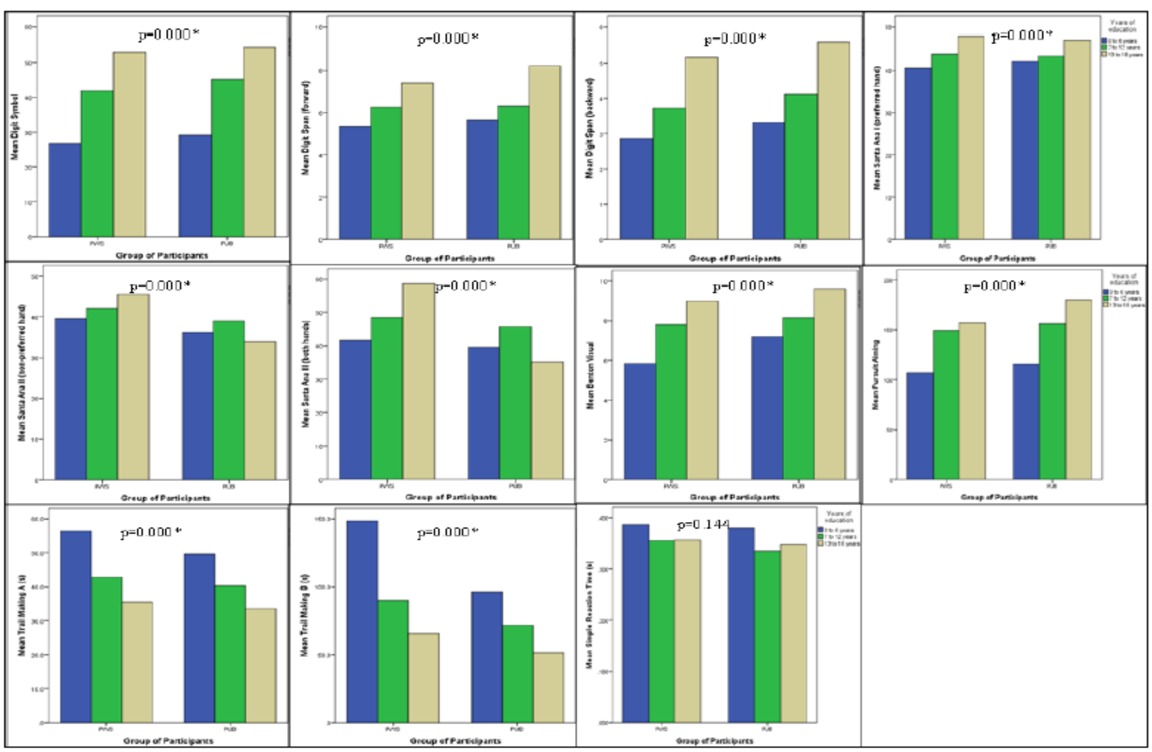


**Fig. 4:** Neurobehavioral performances between the PWS and PUB group according to the years of education received by the participants. Simple reaction time, Trail making A & B records the marks in seconds (s). Test is significant at *P*<0.05

## Discussion

This study provides information on neurobehavioral performance among populations consuming private and public water supply in several palm oil estates. The age of participants ranged from 16 to 65 years old. A significant difference of three years in the mean age was observed among the PWS and PUB participants ($P<0.05$). Only 33 (6.6%) Indian participants out of 500 participants from PWS and PUB took part in the study. The main reason for poor participation from the Indian community was largely due to the high illiteracy rate among them as they do not fulfill one of the inclusion criteria for the study which was literacy.

As for the subjective symptom questionnaire, three out of 37 symptoms were the most prominent in this study: headache, diarrhea and difficulty walking in the dark. This finding was incomparable with a study of population consuming contaminated municipal water supply by using the Profile of Mood State (POMS), which reported a profile of confusion and depression as their early signs of neurotoxicity (30). There are also researchers who recorded the high prevalence symptoms of fatigue, insomnia, tremor in both hands, sleepiness during working and forgetful among workers exposed to lead in Selangor, Malaysia (21).

In general, it was obviously shown that PWS participants had lower neurobehavioral performance compared to the other group of participants especially in tests measuring the function of memory, attention and visual perception-conceptual. Interestingly, those exposed participants were better in Santa Ana which measured their hand-eye coordination. These PWS participants were mostly workers in technical and mechanical job-scope which requires their dexterity skills in daily work.

Several factors influence the performance of neurobehavioral tests. Gender, age and education level were found to have a significant impact on neurobehavioral performance. Female participants in this study performed poorly as compared to male participants in tests that measured latency. This was evident from the Simple Reaction Time and Trail Making A tests by which the male PWS and PUB participants outperformed the female PWS and PUB participants. This finding is in line with Anger et al. (45) and Rohlman et al. (25) who reported that female showed poorer performance than male in motor tests. However, for tests that determined association (Digit Symbol and Trail Making B), females performed better than males.

Younger age category (16-25 years and 26-35 years) from both PWS and PUB performed better on NCTB tests when compared to other age groups. The age-related decline in performance of NCTB observed in this study is in good agreement with Chung et al. (23) who reported that NCTB performance declines with increasing age.

Duration of education also affects the neurobehavioral performance (22). PWS and PUB participants in this study who had education between 13 to 18 years excelled in the NCTB tests when compared with those who had an education of less than 13 years. This finding is in line with those of Chung et al. (23) who reported worsened NCTB performance with less years of education.

Age was found weakly to moderately correlated with neurobehavioral performance for both PWS and PUB participants in all tests. This means that participants showed poorer performance with increasing age. The finding of this study is also in agreement with the finding of Rohlman et al. (25) who reported poorer performance with increasing age for a test that measured coding and complex functioning.

The poorer neurobehavioral performance between PWS participants as compared with PUB participants could be associated with the poor water quality as reported by Siti Farizwana et al. (13).

In this study, more than 60% of participants of the PWS and PUB had secondary level of education. A weak to moderate correlation was found between the level of education of PWS and PUB participants in this study with the NCTB tests. This implies that higher education determines higher neurobehavioral performance among participants (23, 25). Above-mentioned researchers also reported that neurobehavioral outcomes of agricultural and textile workers exposed to neurotoxic chemicals were highly dependent on education level with participants of lower education found to perform poorly as compared to participants with higher education level.

## Conclusion

The PWS participants showed poorer neurobehavioral performance compared to the PUB participants. Their achievements were probably associated with the quality of water supplied to them. Further study such as biological monitoring and molecular epidemiology are recommended to determine the cause-effect relationship between poor water quality and neurobehavioral performance.

## Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.
The study complies with the current laws of the country in which they are performed. The research and ethics approval had been given by the Secretariat of Medical Research and Industry, Universiti Kebangsaan Malaysia Medical Centre (NN-053-2009).

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