Asbestos ingestion and gastrointestinal cancer: a possible underestimated hazard

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Asbestos ingestion and gastrointestinal cancer: a possible underestimated hazard

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ABSTRACT

Introduction: The presence of asbestos fibres (AFs) in drinking water could be linked with gastrointestinal cancers. However, it is not regulated in several countries due to conflicting evidence. 

Areas covered: Some reports mainly associated AF ingestion with gastric and colorectal cancer. Experimental evidence suggested a role for timing and extent of exposure, and showed that ingested AFs induce toxic effects on the stomach, ileum and colon, histological alterations and negative effects at a molecular level, cross the placenta and enter foetal organs (including the liver), and seem able to act as a co-carcinogen agent. Occupational studies suggest associations between asbestos exposure and intrahepatic cholangiocarcinoma, and observations exist indicating the possibility that AFs could enter the liver and bile through enteric absorption.

Expert commentary: A risk threshold (AF concentration in drinking water) for digestive cancers has not been convincingly identified so far and regulations, where adopted, have weak scientific basis and may not be adequate. With further and more definitive studies, evidence might become sufficient to justify monitoring plans, persuade countries with no current limits to set a maximum level of AFs in drinking water and might induce a revision of the existing legislations, pointing to efficient primary prevention policies.

1. Introduction

Asbestos fibers can be released in drinking water mainly through the deterioration or break down of asbestos containing materials, as wastewaters of mining and other industries, leaching from landfills or, more frequently, asbestos cement pipes and water tanks still present in water supply systems [1,2], with concentration of asbestos fibers in drinking water which can vary widely between countries or between different geographical areas in a single country [3]. Furthermore, although 58 countries have issued a nationwide ban on all forms of asbestos [4], new water supply systems could be made with asbestos cement in countries where chrysotile is still not banned. Asbestos cement pipes and tanks were installed broadly in Europe, USA, Canada, and Australia from the late 1920s to the late 1980s, and it has been estimated that asbestos cement pipes accounts for approximately 15% of water main pipe material in North America [5].

In the 1970s, reports on the presence of asbestos fibers in drinking water ($10^5$–$10^6$ fibers/L [6]) and the presence of epidemiological evidence of gastrointestinal cancers in exposed workers [7] generated a wide debate about potential hazards deriving from ingested asbestos. At that time, however, results were contradictory and studies were not conclusive [8].

According to the working group from the WHO International Agency for Research on Cancer (IARC), the ingestion of asbestos fibers is, together with inhalation, a primary source of human exposure to this natural substance, which is toxic and able to induce cancer with a medium long-term latency and in several target organs [2].

Nevertheless, at the moment of publication of the IARC monograph 100 C (year 2012), data on the risk of gastrointestinal cancer deriving from oral ingestion of asbestos have been considered not conclusive. As a consequence, the WHO has not established a guideline value for asbestos in drinking water [9], international regulations have not yet fixed particularly restrictive limits to the concentration of asbestos fibres in drinking water, and in several countries there are currently no limits, although no certain threshold has been identified for the carcinogenic risk at the level of the gastrointestinal tract.

However, there are epidemiological studies indicating an increased risk of cancer of the stomach and colon-rectum following ingestion of asbestos with drinking water [2], it has been shown that ingested asbestos fibers might act potentiating the carcinogenic effect of other toxic agents [10] and, as stated by the IARC working Group, ‘risks of exposure to asbestos in drinking water may be especially high for small children who drink seven times more water per day per Kg of body weight than the average adult’ [2].

Furthermore, despite the existence of great differences in terms of routes and level of exposure, interesting suggestions also derive from recent occupational studies which strengthen the link between exposure to asbestos and cancers at different levels of the gastrointestinal tract [11–13].

The present review is therefore aimed at examining the available evidence on the relationships between ingestion of asbestos fibers (mainly through drinking water) and the risk of digestive cancer, also bearing in mind the large diffusion and the progressive aging of asbestos cement material used for
2. Experimental evidence

It has been showed, in animal models, toxic effects of asbestos fibers on stomach [15], ileum [16], and colon [16–19] (Table 1).

The presence of chrysotile asbestos in an artificial bag placed on the greater curvature of the stomach induced, in rats, cancer of the stomach and the abdominal cavity within 25 months. No tumors were found among the control animals, whereas treated rats developed different types of cancer (adenoma, adenocarcinoma, carcinosarcoma, intestinal adenocarcinoma, peritoneal mesothelioma, abdominal lymphoreticulosarcoma) [15].

Daily ingestion of asbestos fibers with the diet induced in rats histological alterations of the ileum and colon-rectum, and cytotoxicity in the mucosal lining cells of the ileum due to mineral-induced cytotoxicity [16].

A subgroup of F344 rats fed with a diet containing 10% chrysotile and observed over their life-time developed epithelial cancer or non-neoplastic lesions of the colon. Although, in this study, epithelial tumors of the colon were also found in control animals, the cumulative risk of developing colon cancer or non neoplastic lesions of the colon in the long term was greater for asbestos-fed than for control animals. Furthermore, asbestos-fed rats also showed significantly lower tissue levels of 3′-5′-cyclic monophosphate (cAMP) and asbestos fibers penetration of the colonic mucosa, as compared with animals on control diets [17].

The IARC observed, in the year 2012 [2], that the available animal studies were not fully convincing about the direct carcinogenic effect of amphibole asbestos fibers, also at high doses. Further studies are needed in order to clarify this aspect, also considering recent observations focusing on specific molecular pathways potentially linking asbestos ingestion and gastrointestinal cancer.

Previous studies on the pathogenesis of malignant mesothelioma associated with exposure to asbestos pointed to the inactivation of the p53 gene, a tumor suppressor gene [20,21]. More recent observations strengthen this evidence in the case of mesothelioma [21,22], and suggest that deletion or mutation of this gene are very frequent, in humans, also in the case of gastrointestinal cancer, underscoring the relationships between p53 gene and epigenetic factors (small non-coding micro-RNAs) acting as potential tumor suppressors [23]. In the case of colon cancer, in particular, molecular pathways involving the p53 gene are able to induce oxidative DNA damage [24] and to promote revascularization, contributing to tumor progression [25].

Furthermore, the combined exposure to chrysotile and benzo[a]pyrene is a potent inducer of adenocarcinoma and this effect involves the p53 gene [26]. This mechanism might be also possible in the gastrointestinal tract since, in an animal model, it has been shown that amphibole fibers introduced by ingestion are able to adsorb benzo[a]pyrene molecules, inducing DNA damage and potentiating its carcinogen effect [10].

3. Asbestos ingestion and gastrointestinal cancer in humans

3.1. Direct exposure to asbestos in drinking water

Table 2 shows main results from epidemiological studies exploring the association of asbestos in drinking water and the risk gastrointestinal cancer.

Studies mainly published in the ’80 s suggested that asbestos, at concentrations commonly found in drinking water, does not pose a major cancer risk [36,37], although the presence of conflicting results and the difficulties in evaluating the cancer risk by epidemiologic databases and without an adequate consideration of confounders clearly indicated the need for further investigation [37].

The IARC monograph 100 C (updated at 2012) listed the most relevant human studies exploring the risk of cancer occurrence at different levels of the gastrointestinal tract (pharynx, esophagus, stomach, colon-rectum) following asbestos ingestion. The evidence documenting the relationships between nonoccupational exposure to asbestos in drinking water and gastrointestinal cancer were considered by the working group as ‘limited’ and not univocal [2]. The discrepant results from the studies cited in the IARC monograph seem to derive from methodological limitations or weakness, as the prolonged latency needed before the asbestos-related cancer onset, the highly variable exposure levels in the examined populations, and the difficult quantification of the exact amount of ingested fibers over long time intervals and in different age groups [38].

Table 1. Asbestos ingestion and gastrointestinal cancer: main results from experimental studies in rats.

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Exposure duration</th>
<th>Site</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>[15]</td>
<td>25 months</td>
<td>Stomach</td>
<td>100 mg asbestos in a perforated polyethylene capsule. No tumors in control group, different types of cancer in treated animals</td>
</tr>
<tr>
<td>[16]</td>
<td>14 months</td>
<td>Ileum, colon, rectum</td>
<td>Chrysotile 0.5 or 50 mg/day for 1 week or 14 months. Histological alterations in treated animals. Mineral-induced cytotoxicity in the mucosal lining cells of the ileum in rats ingesting 50 mg chrysotile/day for 14 months</td>
</tr>
<tr>
<td>[17]</td>
<td>Life-time</td>
<td>Colon</td>
<td>Diet with 10% chrysotile. Development of cancer or non-neoplastic lesions (higher cumulative risk than in control animals). Asbestos fibers penetration of colonic mucosa. Lower tissue levels of 3′-5′-cyclic monophosphate (cAMP)</td>
</tr>
<tr>
<td>[18]</td>
<td>1 month</td>
<td>Colon</td>
<td>Per os suspensions of asbestos fibers. Aberrant crypt focus induced by crocidolite and chrysotile</td>
</tr>
<tr>
<td>[19]</td>
<td>3 months</td>
<td>Colon</td>
<td>Diet with 6% chrysotile. Chrysotile incorporation in goblet cells, in the cytoplasm of epithelial cells, into the smooth muscle layers</td>
</tr>
<tr>
<td>[10]</td>
<td>24 h</td>
<td>Omentum and intestine</td>
<td>Animals gavaged with crocidolite and anthophyllite fibers and fibers that had been allowed to adsorb benzo[a]pyrene molecules from aqueous solutions. High levels of DNA strand breaks in the cells from the omentum and intestine. Significant potentiating effect of the adsorbed carcinogen on the induction of DNA damage in the omentum</td>
</tr>
</tbody>
</table>
However, the IARC monograph cited only two negative studies exploring the epidemiological relationships between orally ingested asbestos, gastric and colorectal cancer [27, 28]. In the first study [28] authors, documented, in subjects exposed to asbestos in drinking water, an increased risk of cancer occurrence in other extrapulmonary organs (ileum, thyroid, eye, testis, and prostate), underlying the high probability of error in the case of non-significant correlations (i.e. stomach, colon-rectum) and the need for further studies [28]. Of note, the same research group published, two years later, a study showing an increased incidence of colorectal cancer [29].

In the second negative study cited by the IARC working group, authors admit the need to continue the surveillance, due to an insufficient latent period for some exposed groups [27].

Besides these two negative reports, the IARC monograph [2] described other four studies [30–33] demonstrating, with adequate methodology, significant excesses of gastric cancer in cohorts of subjects exposed to asbestos in drinking water, and a study showing an increased incidence of colorectal cancer [33].

A Norwegian study demonstrated an increased risk of gastric cancer (standardized incidence ratio 241, 95% confidence interval 120–431) in male lighthouse keepers ingesting asbestos-contaminated drinking water with a latency period of 20 years or more. Interestingly, no cases of mesothelioma were noticed in this group of examined subjects [34], suggesting the possibility of different toxic pathways in the case of gastrointestinal malignancies.

Another large prospective and population-based cohort study from The Netherlands demonstrated an association between long-term high asbestos exposure, gastric cancer, gastric non-cardia adenocarcinoma, colon and rectal cancer [12]. Although the exposure characteristics (mainly route, intensity and timing) are very different between occupationally and environmentally exposed populations, airborne asbestos may also reach the gastrointestinal tract because of lung clearance.

### Table 2. Asbestos in drinking water and gastrointestinal cancer: main results from epidemiological studies.

<table>
<thead>
<tr>
<th>ref.</th>
<th>Area, asbestos concentration in water, size of exposed population</th>
<th>Association with gastrointestinal cancer</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>[27]</td>
<td>Woodstock (NY), 3.2–304.5 MFL, 2,936</td>
<td>Oral cavity (+), possible effect of smoking</td>
<td>Standardized Incidence Ratios derived from State Cancer Registry. Short period of observation in exposed group.</td>
</tr>
<tr>
<td>[29]</td>
<td>Everett, Washington area, 200 MFL, 200,000</td>
<td>Stomach (+ in males)</td>
<td>Case-control study. Data from tumor registry. Individual validated interviews. Estimated individual exposure to asbestos in drinking water</td>
</tr>
<tr>
<td>[31]</td>
<td>San Francisco Bay area, 0.025–36 MFL, 3,000,000</td>
<td>Stomach (+) Esophagus (+) Pancreas (+)</td>
<td>Correlation with chrysotile content in water independent of income, education, asbestos occupation, marital status and mobility</td>
</tr>
<tr>
<td>[32]</td>
<td>Duluth, Minnesota (USA), 1–65 MFL, 100,000</td>
<td>Stomach (+)</td>
<td>Exposure to taconite asbestos</td>
</tr>
<tr>
<td>[33]</td>
<td>Norway, 1760–71,350 MFL, cohort of 726 lighthouse keepers</td>
<td>Stomach (+) Colon-rectum (+ twenty years and more after first possible exposure)</td>
<td>Follow up from 1960 to 2002</td>
</tr>
<tr>
<td>[34]</td>
<td>Norway, 1760–71,350 MFL, cohort of 690 lighthouse keepers</td>
<td>Stomach (+)</td>
<td>Follow up from 1960 to 1991; 2.4-fold excess in those first exposed at least 20 years prior to diagnosis. No cases of malignant mesothelioma</td>
</tr>
<tr>
<td>[35]</td>
<td>San Francisco Bay area, 0.025–36 MFL, 3,000,000</td>
<td>Stomach (+) Gallbladder (+ in females) Pancreas (+ in females) Esophagus (+ in females) Peritoneum (+)</td>
<td>Cancer incidence ratio. Analysis of confounders (associations independent of income, education, asbestos occupation, marital status, country of origin and mobility)</td>
</tr>
</tbody>
</table>

*positive (+) or negative (–) association between asbestos ingestion and disease.\[ref.\]
and subsequent swallowing, and it is still not certain whether the excess of risk of some digestive cancers observed in exposed workers is due to asbestos ingestion, to asbestos inhalation with subsequent translocation by lymphatic system and blood, or to both mechanisms [2].

Possible associations between asbestos exposure and intrahepatic cholangiocarcinoma have been recently suggested [41,42]. Besides the translocation of asbestos fibers from the lung (a slow process developing over decades of life [43]), the possibility exists that asbestos fibers could arrive to the liver and into bile through gastrointestinal absorption. This hypothesis might be supported, at least in part, by an animal study showing the capacity of orally ingested asbestos fibers to travel from the gastrointestinal tract to both lungs and other abdominal organs [44].

In exposed workers, the presence of asbestos fibers has been documented in colon tissues from subjects with colon cancer [45], and at different levels of the gastrointestinal tract [46,47], including the gallbladder [48] and the biliary tract [49]. In particular, the recent detection of asbestos fibers in gallbladder specimens and in bile from subjects with benign biliary tract diseases and living in an asbestos-polluted area might indicate an hepato-biliary passage of fibers (possibly vehiculated through the enterohepatic circulation), and that this process could also intervene following nonoccupational exposures [48].

4. The extent of exposure: lack of a clear risk threshold

Results from nonoccupational studies indicate that the occurrence of gastrointestinal cancer following ingestion of asbestos in drinking water is possible and that, besides the variable role of confounders, conflicting results mainly derive from difficult quantification of the individual amount of ingested fibers [38]. On the other hand, experimental evidence suggest a major pathogenic role for both the timing and the extent of exposure to orally ingested asbestos [15–17], which seems able to act as a co-carcinogen agent [10] and to induce, in the gastrointestinal tract, histological alterations [16,17] and negative effects at a molecular level [17], also involving altered gene expression [26] with mechanisms similar to those observed in the case of malignant mesothelioma [21,22].

Taken together, these elements should suggest a re-examination of the concentration of asbestos fibers in drinking water to be considered ‘safe’ for humans, also considering the effect of ingested asbestos in different age groups. This last aspect, still unexplored, might be of major importance for environmental exposures starting in infant age, since children are more susceptible than adults to hazards from environmental origin [50,51], subjects exposed as children have many years left to live and this, living for long-term in the same contaminated geographical area, might lead to longer exposure to orally ingested asbestos than adults and, finally, the global amount of water drunk by children is about seven times higher than that ingested by adults [2]. Moreover, as demonstrated in animals, exposure to orally ingested asbestos might start very early (in utero), due to the trans-placental transfer to fetus of asbestos fibers ingested by the mother [52]. This finding has been also confirmed in humans by the detection, in autopsied stillborn infants, of asbestos fibers at the level of the placenta, lung, muscle and the liver [53]. Of note, in this latter study the mean count of fibers was highest in the liver, their detection was not linked with occupational exposure of mothers [53], and the mean length of asbestos fibers (range 0.05–5 µm [53]) was comparable to that generally detected in fibers deriving from asbestos cement pipe system and cisterns [54].

In the case of occupational asbestos exposure linked with digestive cancers, also considering inhalation as the prevalent exposure pathway and translocation of inhaled fibers from the lungs toward other organs [43], the post-inhalation swallowing of fibers (and, thus, a lower concentration of ingested as compared to inhaled fibers) needs to be taken into account [55], also bearing in mind the variety of extra-pulmonary organs involved at the level of the gastrointestinal tract and the long time generally required from translocation of fibers from lung [43].

A large cohort study described an increased incidence of cancer of small intestine and esophagus for cumulative exposure indexes for inhaled asbestos above 80 fibers/mL × years and, in the case of cancer of small intestine, in men having been exposed to asbestos for more than 25 years and for mean exposure levels in excess of 4 fibers/mL [56].

However, in the case of gastrointestinal cancers potentially linked with direct oral ingestion, more than the number of the indirectly swallowed asbestos fibers introduced by inhalation, is crucial the identification of a possible threshold below which asbestos fibers dissolved in drinking water could be considered safe for human health.

The Safe Drinking Water Committee (USA National Academy of Science) estimated that, in an USA population, drinking 2 L/day water containing 0.11 × 10^6 TEM fibers/L (men/women, respectively) may lead to one gastrointestinal cancer case per 10^4 persons exposed over a 70-year lifespan [57]. The US EPA estimated an higher threshold, equal to 7 million fibers/L (MFL), with fibers longer than 10 µm [55].

However, more than 95% of asbestos fibers deriving from asbestos cement pipe system and cisterns (the most frequent origin in an urban settings) are shorter than 10 µm [54], and the estimation procedures applied to calculate the reported thresholds seem to disclose several limitations either in the case of the Safe Drinking Water Committee and the EPA.

In both cases, although the EPA determination underwent some revisions during the last decades, the estimates have been constructed only considering very old studies (up to the year 1985 [55]), Relative Risks for gastrointestinal cancers calculated in the ‘70s-’80s and in a limited geographical area (north America) [57].

Furthermore, the estimates did not consider the real amount of fibers directly ingested, but derived from a double theoretical and indirect approximation based on the conversion from inhaled to ingested fibers (i.e. not considering the amount of fibers directly ingested with water but the swallowing deriving from inhalation) and, in respect to the number of asbestos fibers, on the conversion from light microscopy (LM) to transmission electron microscopy (TEM) [55,57]. The Safe
Drinking Water Committee employed a conversion factor (LM/TEM) of 1:50 (considering selected populations of exposed workers), whereas the US EPA used a conversion factor of 1:200 [57].

All these elements, taken together, may limit the appropriateness of the final assessment of the current threshold, with a clinical risk deriving from the ingestion of asbestos with drinking water which should be underestimated.

Nevertheless, all estimates are based on the presence of a not negligible clinical risk of digestive cancer secondary to the ingestion of asbestos with drinking water, and suggest that this risk may be proportional to the amount of ingested fibers, to latency, and to the amount of ingested water, which might be widely variable according to several physiological (i.e. age, gender) and/or pathophysiological factors.

Besides the current threshold established by US EPA (7 million fibers/L) and irrespective of its appropriateness, of positive results linking gastrointestinal cancer with oral ingestion of asbestos and of results from experimental studies, in the EU asbestos is not explicitly included in the parameter list in the Drinking Water Directive (directive 98/83/EC of 3.11.98) and, as in the majority of countries worldwide (including Canada and Australia), there are currently no legal regulation concerning the maximum contaminant level for asbestos in drinking water.

5. Conclusions

Only a few studies produced strong results, and thus the first goal to reach is to increase the number of studies especially devoted to the identification of a clear risk threshold.

Several experimental and epidemiological studies indicate that the risk of digestive cancers deriving from exposure to asbestos can be originated through different introduction pathways including ingestion, and are also possible in the case of long-term daily ingestion of drinking water contaminated with a still undetermined amount of asbestos fibers.

Definitive studies aimed at the identification of a risk threshold in nonoccupational cohorts are lacking, so far, mainly due to methodological limitations deriving from the long latency period, the coexistence of other risk factors, physiological variables (i.e. age, gender), the absence of an adequate and widely diffused geographical monitoring of the presence of asbestos in drinking water (at least in risk areas), and difficulties in assessing the amount of the individual exposure, that could even start during fetal life.

However, the available evidence appear sufficient to justify adequate monitoring plans in risk areas and the respect of the precautionary [58,59] and prevention principles, should induce countries with no limits to set a maximum level of asbestos in drinking water, and might be sufficient to justify a revision of the existing rules.

6. Expert commentary

The presence of high amount of asbestos fibers in drinking water is a growing problem in a number of countries worldwide, and derives from the extensive presence of asbestos containing materials (i.e. approximately 15% of water main pipe material in north America), to their unavoidable progressive deterioration during time, and to the lack of environmental monitoring procedures, which are completely absent in several geographical areas. As a result, according to previous observations, a number of communities may be exposed to an additional risk factor for the occurrence of digestive cancers, irrespective of the precautionary and prevention principles.

In fact, despite the existence of animal and human studies describing associations between the ingestion of asbestos fibers and the occurrence of cancer at different levels of the gastrointestinal tract (mainly stomach, colon-rectum and, more recently, liver) and the great epidemiological relevance of gastrointestinal cancers, regulations concerning this specific environmental risk are still lacking or probably not really protective. This is principally due (although not fully acceptable) to the persistence of residual uncertainties mainly deriving from methodological limitations or weakness in some previous epidemiologic studies. A negative role seems also to be played by the major importance given, so far, to very old epidemiologic studies and, in terms of the amount of ingested fibers, to indirect and theoretical approximations based on the conversion from inhaled to ingested asbestos fibers and from light microscopy to transmission electron microscopy. All these elements might cause a relevant underestimation in the clinical risk of digestive cancer deriving from chronic ingestion of drinking water containing asbestos. The existing evidence is in some cases convincing, and certainly demonstrate that the risk of gastrointestinal cancer deriving from the ingestion of asbestos is not negligible.

However, available data need to be certainly expanded with further researches in terms of both animal models and epidemiologic studies, in order to reach conclusive results aimed to the confirmation or to the rejection of epidemiological links at the level of different gastrointestinal organs, to better explain the mechanisms of translocation of asbestos from the gastrointestinal tract to the liver and the biliary tract (and their pathogenic relevance), to the complete comprehension of pathogenic mechanisms underlying cancer occurrence in different gastrointestinal organs, but also to the possibility of primary prevention measures, the real ultimate goal in this field.

These purposes can be achieved primarily orienting future research toward the clear identification of a possible threshold level (i.e. an ‘acceptable’ concentration of asbestos fibers in drinking water), the timing of exposure to ingested asbestos considered at risk for cancer development (which, according to some observations, could start during fetal life secondary to the trans-placental passage of fibers), the molecular mechanisms underlying cancer risk/occurrence in the gastrointestinal tract following the ingestion of asbestos fibers, and the concurrent role of other genetic and/or environmental (co-carcinogens) factors. In particular, great interest derives from recent studies pointing to gene-environment interactions (i.e. effects on the inactivation/expression of tumor suppressor genes, oxidative DNA damage) and, at an epidemiological level, from studies exploring the association between the incidence of gastrointestinal cancer (including cancers of the liver and the biliary tract) and long-term exposure to asbestos ingestion, with an adequate
evaluation of the exact amount of ingested fibers and confounding factors.

7. Five-year view

In the short-medium term, results deriving from molecular studies pointing to gene–environment interaction, in particular employing animal models, could contribute to clarify pathogenic mechanism increasing the risk of cancer and/or promoting cancer onset/progression at various levels of the gastrointestinal tract (including the liver and the biliary tract) after exposure to ingested asbestos, also considering the concurrent effect of other toxic agents. In the long-term, longitudinal epidemiological studies in communities living in geographical areas at high environmental risk should be expected, with an adequate analysis of confounders.

Key issues

- Ingestion of asbestos fibres with drinking water, a growing environmental problem in several countries worldwide, has been linked with cancers at different levels of the gastrointestinal tract, including the liver. Data derive from both animal models and epidemiologic studies and, besides a direct effect, also suggest that asbestos ingestion could act as a co-carcinogen.
- Despite the existence of conflicting results (mainly due to methodological difficulties, at least in epidemiologic studies), some studies reported an association between gastrointestinal cancers and the ingestion of asbestos fibres.
- A risk threshold (i.e. an ‘acceptable’ concentration of asbestos fibres in drinking water) for digestive cancers has not been convincingly identified, so far, and some doubts exist about the timing of exposure to ingested asbestos considered at risk for cancer development, also considering that non-occupational exposure in risk areas could start early (i.e. during the foetal life).
- Despite scientific evidence, regulations (where adopted) have weak scientific basis and may not be adequately protective for exposed communities according to both the precautionary and prevention principles.
- Further studies are certainly needed to adequately address unclear points. However, the available evidence may justify monitoring plans, should induce countries with no limits to set a maximum level of asbestos in drinking water, and might be sufficient to justify a revision of the existing rules, pointing to efficient primary prevention policies.

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Papers of special note have been highlighted as either of interest (∗) or of considerable interest (∗∗) to readers.

3. The report from the International Agency for Research on Cancer (WHO).

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cyclic monophosphate (cAMP) and asbestos fibers penetration of the colonic mucosa.


20. Case-control study demonstrating, by individual validated interviews and estimated individual exposure, an association between asbestos ingestion with drinking water and cancer of the stomach in males.


32. Positive associations between asbestos in drinking water and cancer of the stomach, esophagus, and pancreas. Correlation was independent of income, education, marital status, and mobility.


34. Positive association between ingestion of asbestos in drinking water and cancer of the stomach and of the colon-rectum.


